1972

Abstract of 1971 Progress Report

U.S. International Biological Program

ABSTRACT

IBP

DESERT BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

1971 PROGRESS REPORTS

JUNE, 1972

U.S. IBP DESERT BIOME

REPORT OF 1971 PROGRESS

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CENTRAL PROGRAM

PROGRAM PLANNING AND DIRECTION

A major portion of directorial time in 1971 was spent in laying specific plans for 1972 and 1973 in the context of the long-range objectives of the program, and drawing up the first two-year proposal and budget. This process was begun with a Biome Executive Committee meeting in January where several decisions were made in the light of funding probabilities:

(1) Phase out aquatic validation studies after 1971.

(2) Activate no more than four terrestrial validation sites -- Jornada, Silverbell, Rock Valley, and Curlew Valley -- representing the four major U.S. desert types.

(3) Emphasize the Great Basin and Sonoran deserts in selection of process studies.

Guided by these decisions, appropriate process studies were decided upon between the Biome Directorate and the Process Coordinators. Proposals were invited from among the scientists in the Biome, selections made with the aid of ad hoc review panels, edited, and subsequently incorporated into the Proposal volume.

The development and submission of this proposal, along with accompanying Budget volume and two Progress Report volumes, occupied a major portion of the first half of 1971.

N.S.F. site visit in July, subsequent Executive Committee meeting, and the drafting of 45 subcontracts in the latter part of the year, completed that part of the 1971 directorial activities needed to get the 1972 field program underway.

EMERGENCE OF MODELLING PHILOSOPHIES AND PROCEDURES

Two major decisions were made on modelling philosophies and procedures. The first is discussed at some length in this abstract under the modelling section. In brief, the modelling group under Assistant Director Kent Bridges spent the latter half of 1970 in experimenting with alternative modelling modes, and at about the beginning of 1971 settled upon their question-oriented modelling philosophy. Most of their activities in 1971 were spent in developing the models in the modelling section.

By mid or late 1971, it was felt that an additional, complementary modelling approach was needed: development of whole-system models. It was decided that Biome Director, David Goodall, would coordinate this effort, and that a Co-Directorate would be established to provide a second directorate position which could assume a major part of the administrative responsibility, freeing much of Goodall's time for the modelling effort. Deputy Director Frederic Wagner agreed to assume the second Co-Director post.

PERSONNEL AND STAFF CHANGES

In addition to the development of the Co-Directorate, several other staff actions were taken. In order to add greater managerial strength to the organization, an Assistant Directorship for Validation Sites was established. James MacMahon of the University of Dayton was persuaded to move to the Utah State University Zoology Department and assume this post. The post of Assistant to the Directorate was established to add editorial, public relations, and scientific strength. Brien E. Norton, at that time a post-doctorate at Utah State University, was asked to assume this post and a position in the Department of Range Science.

A new Coordinator of Data Processing was also sought during the year. Charles Romesburg, who was just finishing his doctorate in the Department of Systems Engineering at the University of Pittsburgh was offered the position, made several trips to Logan to familiarize himself with the program, and moved shortly after the end of the year. He has a joint appointment in the Department of Forest Science.

Duncan Patten of Arizona State University agreed to serve as Coordinator of Plant Process Studies.

INTERNATIONAL ACTIVITIES

International activities occupied a major part of the time of Central Program staff in 1971, pursuant to the recommendation of the 1970 N.S.F. site visit team. Frederic Wagner spent a substantial amount of the early part of the year drafting a proposal to the Smithsonian Institution for a project to be supported with P.L. 480

funds on the Pre-Saharan fringe of Tunisia. This project was funded and Wagner spent most of the month of June in Tunisia getting the program underway.

In April, David Goodall presented an invited paper for the Symposium on Mathematical Models in Ecology sponsored by the British Ecological Society, then presented a paper on the Desert Biome at a joint meeting of the Scandinavian I.B.P. groups at Upsaala, and then spent time in Israel working with faculty members of the Hebrew University on ecosystem modelling. In September he presented an invited paper on modelling at the General Assembly of I.C.S.U.'s Scientific Committee on Problems of the Environment at Canberra, and in October he attended a Boston meeting called by the American Academy of Sciences to discuss the establishment of an Arid Lands Research Institute in Iran. In December he spent further time in modelling activities at the Hebrew University, planned a trip to establish a Desert Biome program in India but was interrupted by the Bangladesh outbreak, and conferred with personnel of the Rangelands Research Unit of C.S.I.R.O. at Canberra.

Other Biome personnel who traveled abroad include:

(1) John Hanks, Utah State University, to attend meetings on Soil Physics and Technology and on Irrigation in Israel.

(2) Wayne Minshall, Idaho State University, to attend the 18th International Congress of Limnology in Leningrad.

(3) William Nutting, University of Arizona, to attend an I.B.P. meeting on social insects in Warsaw.

(4) Clive Jorgensen, Brigham Young University, to attend an I.B.P. small mammal workshop in Warsaw.

WAGNER TO U.S. EXECUTIVE COMMITTEE

Frederic Wagner accepted an appointment on the seven-man U.S./I.B.P Executive Committee in July. The Committee met in August in Seattle and in October at Oak Ridge.

MODELLING

There were two, relatively distinct modelling programs operating in the Biome central office during 1971: a soils modelling effort under the direction of John Hanks, and the question-oriented modelling effort under the direction of Kent Bridges. The latter effort was the most active in terms of financial and personnel commitment.

During 1971, the group settled upon the question-oriented approach to developing ecosystem models. In general, these models describe the chain of causal relationships linking a limited set of components within the system. In most cases, their area of concern is circumscribed by an explicit question which asks: "What change will occur in component B if component A is changed by X amount?" The chain of relationships between A and B are then described as explicitly as possible on the basis of previous research, and a computer program written to link these relationships into a model which provides output that predicts the changes in component B.

The models are developed through a series of versions, each with the incorporation of increasingly relevant and explicit research data and with increasing correspondence to reality. The first version may be based on existing data from the literature and the intuition or subjective judgment of specialists most familiar with the field. The construction of a Version 1 model quickly points out the deficiencies in existing data and pinpoints the need for explicitly designed research which will provide the necessary information. Versions 2 and 3 are progressive approaches to realism based on the progressive addition of relevant research findings.

Some 16 models were developed in 1971 and these are with brief descriptive statements, as follows:

(1) HOPPER, Version 2. This model examines the effects of multiple species of grasshoppers on multiple plant species. The system operates over several-year cycles, producing an output table of the biomass of each forage species removed by each grasshopper species. The model includes details of the reproduction and feeding behavior of the grasshoppers.

(2) COYRAB, Version 1. The data upon which this model is based are from the studies of F. W. Wagner, C. Stoddart, and F. Clark, on the coyote-jackrabbit interactions in Curlew Valley, Utah.

The rabbit portion of the model will produce population data, with or without coyotes. In addition a disease effect has been included to cause fluctuations in rabbit populations. The amount of vegetation consumed by the rabbits is calculated and may be used to assess the effects of the rabbits and coyotes on the range forage.

(3) CREEK, Version 1. This model asks the question: What will be the effect of removing phreatophytes on the stream level? It contains a complex description of the morphology of a section of stream bed. The water level is dependent on the volume of water input at the head of the section and water loss by evaporation, transpiration, percolation. The remainder is outflow. The vegetation, besides affecting transpiration, modifies the stream flow rate and stream level.

(4) RANGE, Version 1. This model deals with the interactions of rodents and rabbits with the process of range deterioration. The argument which would make them the cause claims that these populations are released by predator control. This can be simulated in this model by a general decrease in post-reproductive die-off of rodent and rabbit populations. According to the argument which would make increases in rodent populations a secondary effect of range deterioration, the deterioration leads, first, to a greater growth of annual and weedy species, on which rodents thrive, and to a measure of brush invasion, providing the combination of cover and of open space which is the best habitat for rabbits.

(5) ANT, Version 1. This model deals with the year-to-year dynamics of the seed crop produced by annuals, the amount of this seed crop consumed and stored by harvester ants, and the supply of seeds for growth in subsequent years. Other ant models are currently under development.

(6) PLANT, Version 1. This is a model of plant growth under competition for water, nutrients and light, designed specifically to deal with the effects of varying grazing patterns. The plant is divided into six biomass types: photosynthetic, non-photosynthetic and standing dead in the above-ground area; absorbing, non-absorbing and standing-dead roots in the below-ground section. The plant is vertically stratified by 10 cm layers in both the atmospheric and soil portions.

(7) PANIC, Version 1. This small model is a primitive description of the actual processes involved in determining the growth of the *Panicum* on the floor of the Jornada playa.

(8) CAMP, Version. This model asks the question: What is the effect of human camp occupancy on the ecology of the area? The site has been considered as a terrestrial campground in a desert of the southwestern United States. The effects considered are the trampling of vegetation and soil and the increased erosion therefrom, burning of dead wood in campfires, garbage and trash deposition and its effect on attracting animals, and "vandalism" such as excess littering, shooting animals, and killing large plants. The total area affected by the campground is divided into subareas of more or less homogeneous use. These are defined, for example, as a campground, a trail, a saguaro stand, and the remaining area immediately surrounding the campground.

(9) CAMEL, Version 1. This model asks the question: What composition of domestic ungulates (cattle), native ungulates (pronghorn), and exotic ungulates (camels) will maximize secondary production in a given desert area? The descriptive names CAMEL, CATTLE, and PRONGHORN have been arbitrarily chosen; any combination of three ungulates may be used by modification of the appropriate parameters.

(10) HILRAIN, Version 1. This probability model provides for different rainfall inputs on a daily basis to slopes with different directions and elevations on a hill or mountain with respect to the direction along which the rain system is moving.

(11) ANNUALS, Version 1. ANNUALS is the first half of an annuals-rodent model needed to answer these questions. The annuals germinate, grow, and set seed in response to season changes, temperature, rainfall (for germination), and soil moisture (for growth). The effects of herbivory and granivory on the population dynamics of the annuals will be simulated when a rodent model has been built and interfaced with this model.

(12) LARREA, Pre-Review. This model was built as a tool for use in integrating the results of growth experiments, by developing and exploring the 5-D growth response surface. Net assimilation is found assuming, in turn, that soil water potential, light intensity and temperature are limiting. The least of the three is assumed to be the real limiting factor. Daytime and nighttime operations are treated separately. The response to temperature is itself a 3-D surface, acclimation temperature as well as actual temperature being involved. The routine curve 3D is used. Exercise of the model to data shows rapid accumulation of biomass, presumably because no litter-fall processes are incorporated. This model operates on the data obtained by Gary Cunningham.

(13) NATURE, Pre-Review. This model produces a seasonal tabulation of qualitative amounts of growth, flowering and germination for five

categories of desert plants. It was built in collaboration with Janice Beatley and incorporates her data from the Nevada Test Site.

(14) PESKY, Pre-Review. This is really three separate models. The basic model, PESKY, is concerned with the life history dynamics of mosquito populations. FRACT presents a technique for increasing the complexity of the production of egg cohorts. ACTIVE presents a technique for the more realistic consideration of daily activity periods.

(15) ANTWERK, Pre-Review. This model addresses the question: How many hours will different species of ants be active given different thresholds for the soil surface temperatures at which the ants will remain active? The basic elements were derived from the soil temperature portions of DEW and the activity-period computational scheme of ACTIVE, a portion of the PESKY model. Daily high and low temperatures are supplied as input to this model.

(16) TERMITE, Pre-Review. Three separate versions of TERMITE models exist. Specific computations involve wood disappearance, activity, and metabolic expenditures.

(17) DEW, Pre-Review. The current version of this model allows the calculation of atmospheric water vapor condensation and/or soil water vapor condensation in the surface soil, given various site parameters.

(18) LIZARD, Pre-Review. This model explores the role of density-dependence in reducing population size variations in *Uta* populations. It was built in collaboration with Fred Turner and is based on his data collected in Rock Valley.

TERRESTRIAL VALIDATION STUDIES

Curlew Valley, Utah — Coordinator: D.F. Balph

Rock Valley, Nevada — Coordinator: F.B. Turner

Silverbell, Arizona — Coordinator: J. Thames

Jornada, New Mexico — Coordinator: W.G. Whitford

Methodological Study

Tueller, P.T., and G. Lorain. Application of remote sensing techniques for analysis of Desert Biome validation sites.

CURLEW VALLEY VALIDATION STUDIES

Soils and Meteorology

The soils of the northern sites are highly variable, due to differences in geological material, former levels of Lake Bonneville and severe sheet and gully erosion. In contrast, the soils of the southern sites are uniform where the texture is silt and loam throughout.

Meteorological and soils measurements are being recorded from both the northern and southern sites. It is expected that a more sophisticated data acquisition system will be installed during 1972.

Plants

All four validation sites were sampled for litter, with the southern site receiving more thorough sampling. The litter biomass for the two northern sites were similar, the highest litter from annuals occuring on site 2. Litter production is probably the same across all four sites.

Root biomass samples have been collected and are awaiting analysis. Preliminary estimates indicated that the greatest root biomass occurs on the southern sites. Sampling of the northern sites was hindered by rocky soils.

Lichens on the southern sites cover approximately 32% of the soil surface with a dry weight biomass of over 200 kg/ha. Lower values are reported for the northern sites. The techniques required to sample the algal-soil crust were developed during this period.

The vegetation of the southern sites has a lower profile and fewer species than the northern sites. A total of 99 species are recorded on the sites.

Plant analyses on the sites have resulted in their typification. The northern sage site is rather uniformly dominated by *Artemisia tridentata* and *Bromus tectorum*. The total biomass on this 70 ha site is 3.48×10^5 kg. The northern grass site is primarily dominated by *A. tridentata* and *Agropyron cristatum*. Total biomass on this 100 ha site is 4.08×10^5 kg.

The southern sage site is co-dominated by *A. tridentata* and *Atriplex confertifolia* with the remainder of the vegetation being primarily *Sitanion hystrix* and *Chrysothamnus viscidiflorus*. Total biomass for this 100 ha site is 2.96×10^5 kg. The most homogeneous site is the southern grass site, resulting from clearing and reseeding with *A. cristatum*. Total biomass for this 100 ha site is 1.89×10^5 kg.

Vertebrates

Grazing by domestic cattle occurs on all the sites. An estimation of the energy budget based on the 3551 cow-days of grazing use on the southern site was calculated to be 315,382 kcal/ha.

A study of the birds during the post-breeding season to post-migratory phase indicate generally decreasing trends in species, numbers and biomass as fall progresses. There are marked differences in sites, with a decrease in species and densities in more open sites. The biomass of the Horned Lark was great enough, however, that the total bird biomass on the southern grass site was greater than the southern sage site.

Jackrabbits are a major constituent of the total herbivore biomass. Daylight censusing of the two northern sites and the southern sage site yielded densities of between 1.02 and 3 jackrabbits/ha.

Small mammals have a higher density on both northern sites than the southern sites, with density estimates ranging from 46.74 kg for the northern sage site to 8.93 kg for the southern grass site.

Invertebrates

The most abundant invertebrate groups on the sites in June were grasshoppers, leafhoppers, Hymenoptera (excluding ants), Coleoptera, and spiders. In September, grasshoppers, ants, Hemiptera, spiders and Coleoptera were the most abundant groups.

Additional estimates were made for harvester ants and arthropods associated with sagebrush.

Microorganisms

Most of the biological activity in the soils is located in the top 3 cm layer, with generally negligible rates below. Vigorous carbon and nitrogen fixation takes place during the wet periods by the surface lichen and algal crust, with much of the nitrogen subsequently disappearing, possibly as volatilized ammonia. Although there appears to be excess nitrogen in the soils, no excess carbon is available to immobilize it.

Microbial numbers decrease gradually with depth, after showing maximum numbers in the 5 to 20 cm layer.

ROCK VALLEY VALIDATION STUDIES

Various abiotic and biological measurements were made on a 46.1 ha (113.9 acres) validation site in Rock Valley, Nye County, Nevada, during 1971. Abiotic measurements included wind speed and direction, air temperature, insolation, rainfall, soil temperatures, soil moisture contents, and selected physicochemical attributes of soils. Biological measurements included estimates of standing crops of annual and perennial plants, together with state changes associated with production of new tissue during the spring of 1971; periodic estimates of the relative abundances of various ground- and shrub-dwelling arthropods; and estimates of densities and biomasses of selected species of vertebrates.

Rainfall during the winter of 1970-1 was below normal so soil moistures during the first months of 1971 were never above 8-9%. Soil moisture declined steadily through August, but following a late August rain increased to 4-8% in September. By early December soil moisture had fallen again to 2-3%: after December rains it increased to 8-10% by the end of the year. No significant differences could be shown between soil moisture at 15 and 30 cm at four stations. Air temperatures were unusually high during mid-January of 1971, but followed normal patterns for the rest of the year. Other climatic conditions were apparently normal for the validation site.

Soil profiles in the vicinity of shrubs (as opposed to bare areas) exhibit aeolian deposits as an A_1 horizon, which also contain higher levels of organic matter and nutrients. In fact, an important generalization is that local geographic differences in soils are less pronounced than differences between soils beneath shrub clumps and that of bare areas. Soils of the validation site are underlain by a massive and strongly-cemented caliche layer (at depths of 30 to 70 cm). This layer is virtually impervious to plant roots and restricts the movement of moisture to greater depths.

The validation site was divided into six reasonably homogeneous zones of vegetation, ranging in extent from 1.41 to 21.21 ha. The vegetation of these zones differed in species composition and the relative abundance of major perennials. In all zones eight shrubs compose from 94-97% of the perennial populations:

Ambrosia dumosa, Ephedra nevadensis, Eurotia lanata, Grayia spinosa, Krameria parvifolia, Larrea divaricata, Lycium andersonii, and *L. pallidum*. *Ambrosia dumosa* is the most common species in all zones. Estimates of density and biomass of plants were developed for each zone and the site-wide estimates were obtained by summing zone data. The standing stock of perennial plants on the validation site as of February 1 was estimated as 1049 kg/ha. This estimate was based on live stem tissue only. During the spring, maximum production of winter annuals was estimated to range from 2.06 to 7.88 kg/ha, depending on the zone in question. The overall site mean was 4.2 kg/ha, 76% of which could be attributed to but seven annual species: *Bromus rubens, Chaenactic carphoclinia, C. fremontii, Chorizanthe rigida, Eriogonum trichopes, Phacelia vallis-mortae* and *Streptanthella longirostris*.

Production of new leaves and new shoots by seven major perennial species in the six zones was estimated to range from 160 to 230 kg/ha, and the overall site mean was about 207 kg/ha. Depending on the zone, this new growth ranged from 17 to 22% of the estimated February standing stock, and about 90% of the new growth was composed of leaves. Flower and fruit production was erratic and sparse. In general, it appeared to constitute only 3-4% of the production of new leaves and shoots. Flower and cone production by *Ephedra nevadensis* was conspicuously better than fruit production by any of the angiosperms. Production by winter annuals was only about 2% of that by perennials. In terms of net primary production, the 1971 growing season was quite poor and some contrasts with previous years are set forth in the text. This can be attributed primarily to the poor moisture conditions following the low rainfall of the winter of 1970-1, and possibly in some degree to the fact that 1970 itself was a poor year.

Arthropods were sampled regularly in pitfalls and by vacumming shrubs. Various spiders (e.g., *Psilochora utahensis*), scorpions (*Vejovis confusus, Hadrurus hirsutus*), solpugids, and tenebrionid beetles were commonly captured in the pitfalls. The local distributions of some of the tenebrionids were highly correlated with soil texture. *Edrotes orbus* prefers coarse soils while *Cryptoglossa verrucosa, Trogloderus costatus, Centriopter muricata,* and *Triorophus laevis* are most common in areas of fine sandy soil. Work is continuing in an attempt to relate the frequencies of pitfall captures to absolute numbers.

Over 800 individual shrubs were vacuumed during the course of the season (*Larrea divaricata, Ambrosia dumosa, Lycium andersonii, Ephedra nevadensis, Krameria parvifolia,* et al.). More than 260 different kinds of arthropods were taken, of which all but a few mites were determined to family. Groups which, at one time or another, exhibited estimated densities exceeding 1000/ha were: chrysomelids, melyrids, tenebrionids (Coleoptera); anthomyids, bombyliids, cecidomyiids, muscids (Diptera); mirid bugs, membracids, braconids, eulophids, formicids, pteromalids, torymids, trichogrammatids (Hymenoptera); coleophorids, geometrids, gracilariids, phalaenids, pterophorids, pyralids (Lepidoptera); acridids, tanaocerids, tettigoniids (Orthoptera). A few groups exhibited estimated densities exceeding 5000/ha (cicadellids, cosmopterygid moths, mealy bugs, phloeothripids) and 10,000/ha (sminthurid collembolans, yponomeutid moth larvae, and thrips). Of 125 families of insects collected by vacumming, 81 were represented by a single species. The most diverse families were the Chrysomelidae, Melyridae, Cicadellidae, Braconidae, Formicidae and Thripidae. The vast majority of insects removed from shrubs were herbivorous and there was a high degree of host specificity. There are at least twenty species of ants in Rock Valley, but nests are inconspicuous in contrast to some of the other validation sites.

The most abundant mammal on the validation site is *Perognathus longimembris*. Spring densities of this species in the two trapping grids were around 10/ha (ca. 70-80 g/ha). Towards the northern edge of the validation site the relative abundance of *P. formosus* increased strikingly, owing to the more sandy soil. The other rodents exhibited spring and summer densities of less than one per hectare and the estimated spring biomass of all rodents was almost certainly less than 250 g/ha. Summer trapping, following the reproductive season, indicated very poor recruitment and observed densities were invariably lower in August than in April and May. In some instances (e.g., *P. longimembris*) the apparent decline was due to a change in trappability rather than a change in actual numbers. Estimated standing stocks of jackrabbits ranged from about 1 gram per hectare in the spring to around 6 g/ha in the fall.

The most abundant reptile is the lizard, *Uta stansburiana,* and in the spring of 1971 observed densities ranged from 35 to 45/ha, with biomass estimates of 133 to 171 g/ha. The estimated biomass of four other species of lizards ranged from around 30 to 100 g/ha, with a total for the four species of around 400 g/ha. Other lizards and snakes might be expected to total some hundreds of g/ha, but no further refinement of this estimate is presently possible. It is almost certainly true that the biomass of reptiles exceeds that of mammals.

Two species of birds bred on the validation site in the spring of 1971: *Amphispiza bilineata* and *Toxostoma lecontei*. Estimated breeding densities were about 0.46 and 0.04 pairs/ha (12.4 and 4.8 g/ha), respectively. Fringillids were the dominant birds during the spring -- probably making up from 60 to 90% of the avian biomass. Twenty-five other species of birds were observed at one time or another, of which the most common were *Dendroica auduboni*, *Carpodacus mexicanus*, *Amphispiza belli*, *Spizella breweri*, and *Zonotrichia leucophrys*. Of the larger birds, the raven was most commonly observed.

TUCSON VALIDATION STUDIES

In 1971 emphasis was placed on the Silverbell Bajada Site, a rather typical Sonoran desert locality.

Aside from the initial inventories, work was started on a perturbation treatment. The one used consisted of repeated passes with four-wheel drive vehicles on a grid covering 18 hectares.

Physical Environment

The soils of the site are quite heterogeneous, five types being represented. Additionally the site is traversed by a complex of ramifying streams and rivulets covering at least 15% of the area. This situation strongly influences the water dispersion and concomittantly that of the plants.

Weather data are recorded automatically and transmitted by radio to Mt. Lemmon where they are then placed on telephone lines connecting to a computer. Data have not been reduced at this writing. The predominant weather fact of 1971, however, was the extremely dry January-July period.

Plants

The density (#/ha) of dominant plants on the site were: *Franseria deltoidea* 1244; *Larrea divaricata* 92; *Cercidium microphyllum* 27; *Acacia constricta* 24; *Olneya tesota* 14; *Cereus gigantea* 7. The biomass (kg/ha) was: *F. deltoidea* 124.8; *Larrea* 385.24; *Cercidium* 1032.4; *Olneya* 2708.9; annual grasses 0.86; annual forbs 0.62; Spurge 0.31.

Extensive data analysis indicates that with all these data there is a rather high variance.

Vertebrates

Density of birds varied during the year from 59-119 birds/100 acres. This includes a total of 40 species being on the site sometime during the year. Biomass varied from 3136-7673 g/100 acres.

Reproductive success was low in 1971, except for hole-nesting species. The dry spring, originally thought to cause this success depression, may not be the factor involved. During the rainy season the success depression continued -- thus eliminating a drought-reproductive success correlation.

Mammal studies in 1971 were confined to the Santa Rita site. There the populations of rodents on both chained and control sites produced a rather stable 800 g/ha biomass. This total consists of fluctuations among the 12 component species which apparently cancel out each other's effect.

Invertebrates

Invertebrate activity was monitored on a 3 ha plot. All major ant nests were located and the area was sampled for consumers of dominant plants. The predominant consumers of above-ground plant parts were both caterpillars.

The larvae of the white-lined sphinx moth, *Celerio lineata*, reached a population of several hundred/ha and an estimated 125 g dry wt./ha or 500 kcal/ha. They consumed a large portion of the dicot annuals on the plot.

A gelechiid caterpillar, *Gelechia albipectus,* consumed practically all of the herbaceous parts of the foothills palo verde *Cercidium microphyllum*. Fecal pellets of this species totalled 14 g/m^2 of palo verde cover, indicating at least 7 g dry wt. of the tiny caterpillars per m^2 of palo verde cover. Other insects (excluding ants, termites and woodbores not studied) did not approach the figures for the caterpillars.

JORNADA VALIDATION SITE STUDIES

The Jornada Validation Site studies, initiated in 1970 with efforts limited to the playa portion of a small watershed, were expanded in 1971 to include a bajada portion of the watershed. In addition, a manipulation site treated with herbicide was initiated. As the objectives of the project are to provide data on the state variables of the desert watershed ecosystem, inventories and measurements of climatic, edaphic and biotic parameters were initiated or continued.

Since the entire watershed could not be studied, two areas were gridded for intensive studies. These were the playa and surrounding fringe (34 ha) and a portion of the bajada (25 ha) through which a major arroyo passes. Trapping or sampling grids were established within these areas so that populations could be monitored for density and biomass changes over selected time intervals. The following statements relate the salient findings for the major investigations.

Environment. Two environmental factors which promoted significant differences between 1970 and 1971 findings are: (1) the failure of the playa to flood in 1971 as it had in 1970, and (2) the usual increased summer precipitation did not begin in 1971 until fall. For these reasons no ephemeral aquatic work was conducted and playa biota productivity was greatly reduced since it was dry during a major portion of the reproductive period or growth season. Monitored environmental factors indicate that minimum daily temperatures were lower (2-3^{o}C) than those temperatures for the bajada, although all other parameters were very similar.

Plant productivity. As suggested, plant productivity on the playa was much lower in 1971 than in 1970. This was especially evident for the playa-bottom species *Panicum obtusum* and *Xanthium strumarium*. The annual biomass pattern of component plant parts (stems, leaves, standing dead, litter, etc.) was, however, similar for both years. Greater density and biomass of annuals and small perennials were recorded around the playa site when compared with comparable bajada species. For shrubs occurring at both sites, generally greater productivity at an earlier date was monitored on the bajada site. Plant calorimetry studies to date indicate little difference in species, sampling date, or state of plant material.

Vertebrate populations and reproduction. The avifauna, presumably due to reduced plant growth and insects in 1971, did not attempt to nest, and only a few succeeded in even laying eggs. During the 1970 and 1971 breeding seasons only 2 nests each year on the playa fledged young. No successful nests were recorded for the bajada site in 1971, although a few nests were recorded to have eggs.

Small mammal or rodent densities on the playa were noticeably reduced in 1971, although diversity did not change. Both playa diversity and density exceeded bajada values. The most abundant rodent on both sites was *Dipodomys merriami*. Rodent movements exceeded expectations on both sites, presumably attributed to the dryness of 1971.

Reptile populations on the playa were markedly reduced during 1971, although diversity remained constant. *Cnemidophorus tigris* was the most abundant reptile on both sites. Both density and diversity were lower on the bajada site, apparently a function of less primary production and heterogeniety of habitats in comparison to the playa fringe.

Total lagamorph densities were greater on the playa, although *Sylvilagus auduboni* densities on both sites were comparable. This, therefore, indicates greater *Lepus californica* densities around the playa.

Invertebrate populations. As quantitative data are not yet available for 1971, only qualitative comparisons can be made. During 1971 fewer insect taxa (families) were collected on shrubs than during 1970. Both *Prosopis* and *Ephedra* harbored nearly twice as many taxa as did *Larrea*, and of these Homoptera and Coleoptera ranked highest. Only minor differences existed between comparable shrubs on the playa and bajada. Insect taxa collected on the playa grasses, *Panicum obtusum* and *Hilaria mutica*, during 1971 were greatly reduced from 1970 taxa levels.

The numbers of ant colonies on the playa fringe are nearly 6 times as numerous per hectare as on the more poorly vegetated bajada. *Myrmecocystus* spp. and *Novomessor cockerelli* colonies are abundantly represented at both sites.

Ground beetle populations, especially *Calosoma* spp. on the playa bottom and *Eleodes longicollis* on the playa fringe, were greatly reduced in 1971. The lack of flooding may have influenced these populations, especially *Calosoma* which was prevalent in the *Panicum* on the playa bottom. Ground beetle populations were considerably lower on the bajada site, where *Stenomorpha* spp. only reached an important status.

Termites were only recorded from the playa during 1971; none being recorded from the bajada site.

The millipede, *Orthoporus ornatus*, was confirmed as a detritus feeder during 1971. *Ephedra* bark is a preferred food. The millipede appears to have few natural enemies, yet shows a size distribution suggesting considerable mortality during early instars. There may be seven to eight instars, each lasting a year, and the final two are the reproductive periods for females.

Microorganisms and decomposition. Playa site samples taken during the year indicated that no consistent changes occurred in soil microorganism counts. Indirect evidence from laboratory studies demonstrated that growth did take place for a period following rains. In moisture-amended soil cultures, numerous motile protozoa were seen which through their predatory action could effectively reduce the microorganism counts to those obtained in the field.

Decomposition rate studies on dried *Panicum obtusum* sewn into mesh bags and placed above and below ground at the playa suggest great variation. Decomposition was nearly 5 times greater in below-ground sites.

No statement as to the effect of herbicide treatment on the biota of the manipulation site can be made at this time.

Remote Sensing of Validation Sites

Aerial photographs of Desert Biome validation sites were taken in 1971 by Tueller and Lorain to assist site Coordinators with the measurement and evaluation of a variety of ecological parameters. Colour, infrared stereo transparencies were obtained with a 70 mm Hulcher rapid sequence camera attached to a single engine aircraft at scales ranging from 1:600 to 1:21,000. Missions over the sites were run in June at Rock Valley, during June and October at Curlew Valley, and in late August at the Jornada and Silverbell sites. At least two scales of photographs were obtained at each site; the larger scales being intended to provide information on species number, distribution of species and soil surface characteristics, the small scales being useful for depicting plant community distribution and defining topographic features. A degree of ground truth was established for the Silverbell and Jornada sites, while at the Rock Valley and Curlew Valley sites the interpretation was left to competent personnel with the offer of assistance as required. By means of the photographs, it was possible to separate communities, make reasonably accurate identification of species, measure vegetation cover by species and community, determine species density and distribution, and obtain considerable information on relief features such as gullies and washes. Since live vegetation appears in shades of red on film recording infrared reflectance, dead plants could be distinguished as a separate class.

TERRESTRIAL PROCESS AND METHODOLOGICAL STUDIES

ABIOTIC

Dirmhirn, I. The radiative environment and the surface temperature on a microscale in a sagebrush biome.

Dutt, G., with J. Hanks. Predicting nitrogen transformations and osmotic potentials in warm desert soils.

Jurinak, J.J., and R.A. Griffin. Factors affecting the movement and distribution of anions in desert soils.

Qashu, H.K., D.D. Evans and M.L. Wheeler. Soil factors influencing water uptake by plants under desert conditions.

Sammis, T., H.K. Qashu, J. Ryan and J. Thames. Water balance techniques. I. Sampling soil moisture changes on the Santa Rita validation site. II. Channel transmission losses on the Santa Rita validation site.

Coordinator: R.J. Hanks

Surface temperature and the radiative environment were examined on a microscale by Dirmhirn in a sagebrush community in Curlew Valley. Horizontal and vertical profiles and albedo values were measured with pyranometers and a net radiometer during clear summer days. The purpose of this particular study was to describe the radiative climate encountered by a small animal or by low-growing vegetation. Surface temperatures of more than 50°C were common in bare places, with extremes beyond 60°C recorded near reflecting bushes. By means of a series of measurements taken from ground level to 20 cm above plant height, isolines of equal radiation were drawn around a typical sagebrush plant to make up a three-dimensional picture. The influence of the shadow pattern cast by the bush caused considerable variation in the isolines with time of day. Along the vertical profile through the canopy of a sagebrush plant, solar and scattered radiation decreased with depth. Albedo measured with a pyranometer at the same points, on the other hand, increased with depth, partly due to the spectral change in radiation as it filtered through the leaves. Wide variation resulting from the impact of sun and shade spots were evident in the top portion of the vertical profile through a bush.

Sammis et al. conducted a methodological study on the Santa Rita site near Tucson to test the applicability of a gamma ray unit to index soil moisture content. One minute radiation counts were made under both dry and moist conditions to depth of 90 cm, and corresponding gravimetric samples were analyzed. Sampling errors were determined and a simplified accretion-depletion model was developed based on soil density changes to estimate moisture regimes from rainfall data. In a companion study, the authors studied channel transmission losses on the site. An attempt was made to simulate flow events and develop some predictive models. A number of mathematical estimators in the literature were considered, tested and manipulated. Philip's equation ($Q = At^{1/2} + Bt$) had correlation coefficients ranging from 0.87 to 1.00 when calculated accumulated infiltration was compared with field measurements. Infiltration rates were affected by initial moisture content and soil structure of the stream bed. Consumptive use measurements of the riparian vegetation showed that transpiration rates diminish linearly proportional to the ratio of available water to that present at field capacity.

Thermocouple psychrometers were used by Qashu et al. to compare the spatial and temporal variations in soil moisture potential within vegetated and non-vegetated plots at the Santa Rita site. The observed potential variations were related to atmospheric and plant variables. Measurements taken on the non-vegetated site proved that the Peltier-type psychrometer can measure the true total moisture potential at a given point in the soil, provided that extreme temperature or moisture fluctuations do not occur. Though absolute moisture contents could not be determined directly from psychrometer data, once a soil has been calibrated the technique can measure soil moisture content changes with a considerable degree of accuracy. Potentials below -50 bars or above -1 bar were outside the practical range of the psychrometers employed. A pronounced diurnal trend in moisture potentials were demonstrated at the 30 and 60 cm depths, but not below the latter level. There was close correspondence between curves for diurnal temperature variation and moisture potential variation. Comparison between the vegetated and non-vegetated plots over a season revealed that vertical soil temperature profiles were similar in both cases, but moisture potentials under the vegetated plot responded faster to rainfall than those under bare ground. Negligible amounts of water were drawn from the top 15 cm by transpiration of *Celtis pallida*; this surface zone did not appear to affect the plant's growth cycle. Moisture levels in the region between 30 and 150 cm, however, appeared to exert considerable control over the growth pattern of the plant. Though horizontal movement of water occurred away from the plant during wet periods, little if any horizontal moisture movement occurred as a result of gradients produced by root extraction of water. The presence of a plant significantly altered the spatial distribution of the parameters governing moisture movement in the soil.

Research conducted by Jurinak emphasized the chemical characterization of phosphorus in soil under both crested wheatgrass and sagebrush communities on the Curlew Valley site. The pattern of soil phosphorus distribution in the soil with depth (down to 160 cm) was identical in both plant communities, and no seasonal variation in plant-available phosphorus or in soil phosphorus distribution could be detected. When soil phosphorus was fractionated, 75-90% was shown to be in the inorganic form, predominantly calcium phosphate (80% of inorganic fraction) which regulates the concentration of phosphorus in the soil solution. Available P was highest (25 - 30 ppm) in the surface 0-3 cm, but below 15 cm the soils were agronomically deficient in available P (< 10 ppm). The data suggest that adequate levels of phosphorus are being supplied to the vegetation from only a relatively shallow layer of surface soil. Organic P distribution in the profile was found to be the inverse of the inorganic fraction. Maximum organic P occurred at depths corresponding to regions of maximum root density, where 20 - 25% of the total P was organic. Below this zone organic P decreased to about 3% of total P. Concentration of total P at the soil surface varied between 900 - 1100 ppm; it decreased rapidly with depth to reach a minimum 500 - 550 ppm at 28 - 40 cm and then remained constant at 600 - 700 ppm below 70 cm. These data suggest that there was no cycling of P below a depth of 70 cm.

Dutt took his verfied model predicting nitrogen and salt content of drainage water from irrigation agriculture and attempted to apply it to simulate nitrogen transformations, nitrogen movement and plant intake of nitrogen in a warm desert soil under range grass. The moisture movement portion of the model, however, proved to be inadequate for the two-layered situation encountered in the desert soil. Hanks has undertaken to supply a suitable model to correct this impediment and permit a satisfactory run of the nitrogen transformation and plant uptake portions of the model. In the meantime, an incubation study was initiated to assess the application of the nitrification portion of the model to soils under conditions of low moisture content and high temperature characteristic of warm desert soils. Preliminary data indicate that nitrification rates in desert soils with pH < 7 may be at least an order of magnitude less than those predicted by a model designed for alkaline soil conditions. Data from the incubation study will be used to develop a more sophisticated subroutine for nitrification in soils.

MICROORGANISMS

Lynn, R.I., and R.E. Cameron. The role of algae in crust formation and nitrogen cycling in desert soils.

O'Brien, R.T. Proteolytic activity of soil microorganisms.

Skujins, J. Nitrogen dynamics in desert soils. I. Nitrification.

Tucker, T.C., and R.L. Westerman. Gaseous losses of nitrogen from the soil of semi-arid regions.

Coordinator: E.E. Staffeldt.

Lynn and Cameron examined the genetic composition of algal crusts and properties of soils bearing crusts on the validation sites. Samples of the surface 2 cm yielded high numbers of heterotrophic aerobic bacteria, microaerophiles, nitrogen-fixing bacteria, yeasts, molds, algae and protoza, at all four sites. Apart from the Jornada playa, there was relatively low abundance of nitrogen-fixers such as *Nostoc* and *Scytenema* algae. In addition to higher *Nostoc* counts, the playa was distinguished by typically aquatic genera even though it did not flood during the sample year. Common soil algae found in both hot and cold desert crusts include *Chlorella, Oscillatoria* and *Chlorococcum*. The cold desert yielded a richer algal flora than any of the hot desert sites.

Soil samples collected beneath algal crusts under dry conditions from Jornada and 2 sites near Tucson displayed low C:N ratios (<10) and insufficient moisture levels for microbial activity, though moisture tended to increase with depth while microbial counts decreased.

As part of the validation study at Curlew Valley, Lynn developed a reliable technique for algal biomass of soil crusts based on measurement of chlorophyll a content. The principal advantage of the technique is its indifference to the presence of non-algal contaminants in test samples.

Little is known about proteolytic activity of microorganisms in desert soils. Working on samples from the Jornada site, O'Brien looked at decomposition of protein into amino acids and peptides, and ammonia formation from the substituent amino acids. Using the Lowry colorimetric technique, he found colony forming units at densities ranging from 8 to 17 x 10^5 per gm on the bajada and 1.5 to 9 x 10^5 per gm in the playa soils. Percent proteolytic bacteria ranged from 0 to 77%, with a mean about 50%. His results indicate that vertical and horizontal distribution of proteolytic bacteria in the playa and bajada soils is remarkably uniform. Though the playa soils showed lower densities and lower proteolytic activity, total plate counts and proteolytic counts showed no obvious correlation between activity rates and numbers of organisms. Proteolysis rates increased several-fold from 20 to 37° incubation temperature. Preliminary results on ammonia formation indicate that as much as 80% of amino nitrogen in protein is converted to ammonia, which is likely to remain in the volatile state and be lost to the atmosphere under hot desert conditions. Further studies should show whether this constitutes potential N drain to the desert ecosystem.

The potential for gaseous loss of nitrogen from desert soils was demonstrated by Tucker and Westerman. Manometric techniques were used to measure gaseous products when soil samples ammended with $^{15}NO_3$ were incubated under an argon atmosphere with and without the addition of glucose. The evolved gases were analyzed by gas chromatography or mass spectrometry to identify constituents and their relative amounts. Two soils were employed in the study: a sandy loam from Santa Rita site and one from an agricultural soil near Tucson. The amount of gaseous loss was influenced greatly by the amount of initial soil organic matter (much higher in the agricultural soil) and the additions of glucose as an energy source. Complete reduction of NO_3^- to N_2 required an adequate source of energy, either organic matter or added glucose. Reduction of NO_3^- to N_2O (the primary initial product of reduction) occurred with less available energy, as indicated by evolution of N_2O from samples taken at lower profile depths. The gaseous loss of added NO_3^- after 18 days incubation ranged from 23 to 56% without glucose, and from 41 to 67% with glucose added. The data show that glucose amendment was not mandatory for nitrate reduction under anaerobic conditions. More than half the added NO_3^--N was lost from the surface desert soil and one-fourth to two-fifths from the sub-surface (down to 95 cm) samples without the addition of glucose. It must be remembered that the incubated samples were moist. The gaseous loss of nitrogen from soils in their normal dry state was not encompassed by this particular study.

In a study of nitrogen fluxes and pools in Curlew Valley soils as a function of seasons, Skujins examined (in the laboratory) nitrification, ammonification, proteolytic activity and biological activity, and potential activity values for depths to 130 cm, were examined. Ammonium-nitrogen values fluctuated between 0.7 and 104 ppm, with maximum amounts in the top 3 cm during October and November. During winter the concentration decreased to an average 5 ppm, and then rose in the spring -- a pronounced change evident throughout the profile. In the profile below 5 cm the ammonium-nitrogen levels are generally low and never exceed 10 ppm. Preliminary experiments indicated that much of the ammonium in the fall were lost by volatilization due to high soil pH values. Nitrate-nitrogen values were below 1 ppm, with increases above 1 ppm in the spring and fall -- the highest levels evident in the top 3 cm and in the 5 - 20 cm layer. Since fluctuations in soil moisture were detected to only about the 50 cm depth, it appears that leaching of any nitrogen components to deeper strata is of no importance. The contribution of inorganic nitrogen to the total soil nitrogen was negligible (0.05 to 0.2%). Soil organic nitrogen varied between 0.04 and 0.3%, with the highest values in the surface 3 cm. Increases of about 0.05% in organic nitrogen are evident in the spring and lesser increases in the fall, but the added nitrogen is lost during the summer and winter months. These seasonal influences disappear below 20 cm. Organic carbon values varied between 0.3 and 2.5% and parallel the total nitrogen values in distribution and seasonal fluctuation. C:N ratios were low throughout the profile (6 to 12). Total biological activity was based on measures of dehydrogenase activity. The surface 3 cm exhibited about a 10-fold higher activity than deeper zones. Proteolytic activity showed a similar relationship to depth, and both were almost absent at the meter layer. This result contrasts with the findings of O'Brien.

The present results indicate that vigorous carbon and nitrogen fixation is carried out by the surface lichen and algal crusts during the wet periods. During moist and warm periods, most of the added biomass is decomposed with a subsequent release of ammonium. The combination of high pH and long drying periods promotes volatilization of ammonia, and only a negligible fraction of the fixed nitrogen appears to enter the soil's biological cycle. Verification of these conclusions is needed in the field with ^{15}N and ^{14}C techniques.

PLANTS

Bamberg, S., and A. Wallace. Gaseous exchange in Mohave desert shrubs.

Cable, D.R. Seasonal use of soil moisture by mature velvet mesquite (*Prosopis juliflora* var. *velutina*).

Caldwell, M.M., R.T., Moore, R.S. White and E.J. DePuit. Gas exchange of Great Basin shrubs.

Cunningham, G.L., and F.R. Balding. The effects of environmental factors on rates of primary production of two desert grass species.

Goodall, D.W., S. Childs and H.H. Wiebe. Seed reserves in desert soils.

Hironaka, M., and E.W. Tisdale. Growth and development of *Sitanion hystrix* and *Poa sandbergii*.

Klemmedson, J.O., and E.L. Smith. Distribution and balance of biomass and nutrient in desert shrub ecosystems.

McKell, C.M., and L.G. Kline. Role of annual grasses and shrubs in nutrient cycling of Great Basin plant communities.

Patten, D.T., and R.A. Nisbet. Productivity and water stress in cacti.

Pearson, L.C. Effects of early and late irrigation in the net productivity of *Oryzopsis hymenoides* in eastern Idaho.

Ting, I.P., H.B. Johnson, S.R. Szarek and G.D. Brum. Gas exchange and productivity for *Opuntia* spp.

Wallace, A., and S. Bamberg. Rate of transport of photosynthate to root systems of desert shrubs.

West, N.E. Biomass and nutrient dynamics of some major cold desert shrubs.

Coordinator: D.T. Patten

Vegetation plays a principal role in the characterization of a desert ecosystem, and this importance was underlined by the funding of thirteen plant studies. The projects tend to fall into three cateogories: biomass and nutrient studies, gas exchange and photosynthesis studies, and grass studies, both annual and perennial.

At the Santa Rita Experimental Range in Arizona, Klemmedson and Smith measured the distribution and balance of biomass and nutrients in a mesquite (*Prosopis juliflora*) ecosystem. For an average-sized mesquite, 6.7% of organic matter of the above-ground portion is in leaf material, the remainder in branches of which roughly one-third (27 Kg) are dead. Leaves had a far lower C:N ratio than live or dead branches, so that 14% of above-ground N was in the leaves of an average tree and 64 and 20% in live and dead branches respectively. For small trees (less than 2.5 m canopy diameter) there was a greater fraction of above-ground nitrogen in the leaves (up to 29%) than in larger specimens (down to 2%). Flowers contained the highest proportional nitrogen content (3.67%); leaves and current branches in spring had 3.30 and 2.28% nitrogen, respectively, but the percentages fell to 2.83 and 1.98% by early fall. In contrast, the nitrogen content of branches and dead wood increased significantly from spring to early fall levels, and their C:N ratios were correspondingly reduced. No fruit was formed during 1971. A relationship was evident between the mesquite trees and understory vegetation and mulch. Weights of shrubs, forbs and mulch were highest beneath the canopy and decreased toward the canopy edge. Total understory nitrogen followed the same distribution pattern.

Cable discovered a similar distribution of water removal from the soil beneath and surrounding velvet mesquite (*Prosopis juliflora* var. *velutina*) between July and December, 1971. Soil moisture was measured at 25 and 100 cm depths by the neutron probe method at intervals radiating from the bases of live and dead mesquite trees at Santa Rita. Moisture content was relatively uniform beneath the canopy of live trees, and was somewhat lower than moisture content beyond the tree crowns by several percentage points. Cable concludes that mesquite roots were about equally active in using moisture from beneath the crown, and displayed a low capacity for extracting moisture from openings between the trees. Moisture content beneath dead trees showed the highest values. As would be expected, moisture content at the 25 cm depth fluctuated with precipitation; the 100 cm depth did not respond until December.

In the cold desert vegetation at Curlew Valley, West studied the biomass and nutrient dynamics of three major shrub communities dominated by *Atriplex confertifolia, Eurotia lanata* and *Artemisia tridentata*. The study was a continuation of a project undertaken with Caldwell in 1970. The present work was designed to relate data on plant growth and biomass with mineral nutrient content within the soil, litter and plant compartments. The completion of 1971 research permitted tentative conclusions to be drawn from three years of data. Roots account for 74 and 87% of the plant biomass in the *Eurotia* and *Atriplex* communities respectively. This and other differences in relative amounts of plant biomass and litter are primarily related to the contrasting growth habit of the two species. Total biomass estimates of 1,848 and 1,730 g/m^2 for the two communities were not significantly different. Higher values of Na in *Atriplex* shoots suggested higher salinity tolerance and salt-pumping activity of this shrub. Higher cation content of new growth compared to old growth demonstrated that cation nutrients were labile. Nitrogen exhibits a tight intra-system cycle with estimated turnover times of 6.3, 4.4 and 6.6 years in *Eurotia-, Atriplex-* and *Artemisia*-dominated systems, respectively. More work with radio-tagged elements will be needed to elucidate the nitrogen fluxes in the systems. Shoot and root litter appeared to be the most readily-available source of inorganic soil nitrogen for plant growth in both *Atriplex* and *Eurotia* communities. Compared to the entire ecosystem, only about 0.3 - 0.6% of the biologically-incorporated nitrogen is found in the above-ground biomass, and of this amount only about one-third is associated with new leaf and twig growth. In the *Atriplex* community, the mean rate value for total litter nitrogen turnover probably lies between 4 and 8 years. Root biomass decreases precipitously within the 60-90 cm depth, probably due to high soil salinity reducing water uptake and root growth at this level. Roots proliferate in greatest quantities near the surface where leaching reduces salinity and osmotic potential. Roots were not found, however, in the surface 3-5 cm in either the *Atriplex* or *Eurotia* communities; this portion of the soil is subject to rapidly fluctuating moisture and temperature conditions. Though nitrogen concentration in the surface 2 cm is equivalent to the average nitrogen concentration of agricultural soils, the desert soil nitrogen drops sharply down the profile and this could make nitrogen the element most often limiting plant growth (second to soil water availability). All C:N soil ratios fall within the range of 8 to 15 (median 10 to 12), with subsurface ratios greater than surface ratios. The soils are by far the largest reservoirs of nitrogen and organic matter in the system, accounting for about 96% of the nitrogen and 87% of the organic matter. A very small fraction, however, is involved in the annual nitrogen cycle.

In a study of eight Mohave desert shrubs, Wallace et al. found that it could be feasible to use linear regression in the estimation of root weights from observed stem or shoot weights, or to estimate the below-ground component of primary production from estimates of that distributed above-ground. Root growth of eight perennials grown in a glasshouse was followed as the plants increased in size. Increasing root weight was statistically compared with increasing weights of stems and leaves. The mean difference between observed above-ground weights and root weights calculated from linear regression for all species was 21.8%. Relationships from leaf weights alone were almost as good as those from stems. The mean percent of plant biomass in the roots was 17.7%, with a mean below-ground biomass increase of 19.5% (26% for *Franseria dumosa*). *Franseria dumosa* shoots were exposed to $^{14}CO_2$ and the distribution of labelled carbon in roots, stems and leaves was measured at 1 week, 2 months and 5 months. Only about 15% of the photosynthate was stored in the root. Much of that stored in the stems was available for new leaf growth, the major storage organs being the leaves and then the stems. The ratios of root and stem weights obtained from some field samples were more variable than for glasshouse-grown plants.

Patten examined biomass increases of prickly pear cactus (*Opuntia phaeacantha* var. *discata*) relative to environmental factors of temperature and moisture availability and internal factors of plant temperature and moisture stress. Biomass measurements taken *in situ* from a site east of Mesa, Arizona; specimens were collected from this locale for CO_2 exchange studies in eitner the fresh-cut condition or following a period of growth in pots. Biomass estimates based on dimensional measurements in the field showed some fluctuations correlated with periods of rainfall and some apparently unrelated to any one environmental phenomenon such as temperature or rainfall. Two possible explanations for the latter fluctuations are higher respiration rates over photosynthetic rates in response to drought, or translocation to growing points. CO_2 exchange rates showed little correlation with solar radiation but reacted rather to seasonal variability as measured by compensation-point temperatures (temperature at zero CO_2 exchange). The compensation-point temperatures lagged slightly behind seasonal temperature changes, the lowest compensation-point temperatures occurring in March and April and the peaks occurring in late August through September. Colder temperatures increased daily net CO_2 uptake during the months of December through February when night minimum temperatures were far below the night compensation point and maximum day-time temperatures were only slightly above the day compensation point. Rapid growth of pads followed this period. Metabolic processes within succulents such as cacti are less dependent on air temperature than internal temperature, whose influence on CO_2 exchange rate of *Opuntia* pads can best be shown when there is little water stress in the plant. Comparison of day and night CO_2 exchange curves from plants collected during different seasons and which had little water stress, permitted estimation of relative photosynthetic rates as influenced by temperature during the different seasons. Cacti with water stress have reduced metabolic rates and minimal net CO_2 exchange. Under stressed conditions, plants collected during the cool season displayed very little net photosynthesis (difference between day and night rates), and it occurred only at low temperatures. Healthy plants characterized by good plant vigour had greater rates of CO_2 influx or efflux, a state which could be detrimental during the cold season with above-normal day-time temperatures.

Productivity and gas exchange of three species of *Opuntia* (*O. basilaris, O. bigelovii,* and *O. acanthocarpa*) from two sites in the Deep Canyon desert, California, were measured by Ting et al. Differences in life zones of vegetation account for differences in standing crop biomass between the two sites -- one site at 925 feet elevation being in the Lower Sonoran zone and the higher site (2,575 feet) being in the Upper Sonoran life zone. The portion of total biomass contributed by succulents, however, was similar for both sites. Estimated rates of net primary productivity for the three species were relatively low, ranging from -2.8 Kg/ha/yr to only 68.7 Kg/ha/yr (0.35%) at the higher site with the higher annual precipitation. Though dark CO_2 assimilation in the desert environment was relatively low (0.5 - 1 mg $CO_2/dm^2/hr$), any dark-fixed CO_2 was retained within *O. basilaris* during the following hours of daylight. Cuticular and stomatal impermeability during daylight hours aided the retention of CO_2 and water vapor. During summer, gas exchange and transspiration losses of water vapor were restricted to periods following rainfall, with daylight CO_2 fixation still at neglible rates even though carbon assimilation is taking place. It is suggested that there is a re-cycling of carbon via a diurnal fluctuation in total organic acids and sugars -- an important physiological adaptation allowing continued synthesis of necessary compounds in *Opuntia* species during periods of water stress. Estimates of dark CO_2 assimilation and subsequent photosynthetic carbon assimilation are 1 to 1.5 times the rates of CO_2 assimilation recorded elsewhere in the literature for *O. basilaris*. The stomata appear to be controlled more by environmental parameters (i.e., light and temperature) than by plant water status. Availability of soil water directly regulates plant water status, which does not change at soil water potentials below -40 bars. Maximum rates of water absorption appear to be during daylight hours.

Bamberg and Wallace measured rates of gaseous exchange in Mohave desert shrubs in order to obtain seasonal values for important plant species. Five shrub species were tested in a compensating null-point Scemens' plant chamber: *Ambrosia dumosa, Krameria parvifolia* and *Larrea divaricata* in the field, and *Lycium andersonii, L. pallidum* and *A. dumosa* in the glasshouse. Average values for CO_2 uptake and transpiration for the five shrub species indicate that during late spring most plant species are still carrying on photosynthesis. A decrease in water utilization was evident throughout May and June at a time of increasing temperature and moisture stress. In the case of *Ambrosia dumosa,* lowered soil moisture was associated with decreased CO_2 uptake rate and less efficient water utilization. For *Lycium pallidum,* both transpiration and the rate of water use per milligram of CO_2 increased at higher temperatures.

In another gas exchange project, this time on cold desert shrubs, Caldwell et al. measured photosynthesis, transpiration and dark respiration of *Eurotia lanata* and *Atriplex confertifolia* under both field and controlled conditions in relation to leaf temperature, soil water potential, soil temperature, plant moisture stress and irradiation. In response to ambient conditions, *Eurotia lanata*, having a C_3 photosynthetic pathway, exhibited maximum gas exchange rates during the spring months of April and May. By early August net photosynthetic activity was curtailed and transpiration rates greatly depressed. For *Atriplex confertifolia,* a C_4 pathway plant, photosynthetic and transpiration rates were also at their highest levels in spring. However, positive net photosynthesis and transpiration were maintained well into October. *A. confertifolia* possessed a more favorable water use efficiency for photosynthesis under all environmental conditions in the field. In laboratory studies, positive net photosynthesis and transpiration activity were exhibited by both species under water stress conditions exceeding those found in the field. From March to October, the two species progress through ten easily-recognized phenological stages associated with changes in leaf-age composition, physiological states and increasingly severe plant moisture stress. The change in moisture stress is reversed in late August and early September in response to fall precipitation and higher relative humidities. Transpiration and net photosynthesis varied greatly with phenological status and environmental history. For *E. lanata* there is little apparent acclimation taking place in terms of relative photosynthesis at different leaf temperatures. For *Atriplex,* however, there is a dramatic shift both in the optimal temperature for photosynthesis and in the upper and lower limits of photosynthetic activity. Early in the season, optimal photosynthesis was occurring at ca. 12°C leaf temperature and the upper compensation point (zero net CO_2 exchange) was at 37°C. At maximal leaf temperatures during mid-season, optimal photosynthetic rate takes place at leaf temperatures of 32°C and the upper thermal compensation point is 50°C. While *Atriplex* did not appear to undergo acclimation in terms of dark respiration potential as a function of leaf temperature, *Eurotia* experienced abrupt shifts in dark respiration rates as a function of leaf temperature at different times of the year. In general, respiration rates were higher at cooler temperatures. Preliminary analyses of gas exchange measurements for *Artemisia tridentata* indicate patterns of photosynthesis and transpiration activity similar to those found for *Atriplex* and *Eurotia.*

Cunningham and Balding developed two models to predict net CO_2 exchange for desert grass species, using as the driving variables irradiance, air temperature and soil water potential. One model ("PSYN") assumed that one of the driving variables would be rate-limiting to net CO_2 exchange; the second model ("GAS") did not make this assumption. Input and validation data for both models were obtained with a differential infrared gas analysis system using potted plants of *Tridens pulchellus* and *Panicum obtusum* in a controlled environment chamber. The models were tested against actual rates of CO_2 exchange measured in the laboratory. Though each model produced predicted response curves of similar shapes, the PSYN model showed less sensitivity to changes in irradiance at low temperatures, and less sensitivity to temperature changes at low irradiance. Both models, however, provided reasonably accurate estimates of actual net CO_2 exchange over the ranges of irradiance and temperature measured.

A comparison in growth and development of *Sitanion hystrix* var. *hystrix* and var. *californicum* was made by Hironaka and Tisdale. Var. *hystrix* developed more rapidly than var. *californicum* (10 to 14 days earlier) but produced smaller plants. On a per unit leaf area basis, var. *hystrix* had higher rates of photosynthesis, respiration and transpiration, which may be related to its earlier development rate. Root:shoot ratio changed with stage of development, the highest ratio occurring during the leaf to boot stage. The ratio was also affected by soil temperature, since cool to moderate soil temperatures favored root growth whereas high temperature favored shoot growth. Optimum temperature for both shoot and root growth appeared to be about 25°C for both varieties. Considerable root growth was produced by seedlings grown in soil temperatures at 5°C, which in the field would permit the species to grow during the early spring before moisture stress became significant.

The effects of water and temperature on net productivity of two grasses (*Stipa comata* and *Oryzopsis hymenoides*) were studied by Pearson on sites in the Rexburg area of eastern Idaho and in Curlew Valley. Irrigation treatments were applied to uniformly-selected plants in the field to simulate extra early spring precipitation, late spring, and both early and late spring precipitation. Dimensional measurements were made on culms and leaves, and whole plants were harvested periodically and their biomass partitioned into roots and shoot parts. Some satisfactory correlations were obtained between dry weights and dimensional or numerical measurements. Late irrigation had a greater effect than early irrigation in increasing yield. The data is inconclusive at this stage on litter and soil properties in relation to the treatments.

McKell and Kline studied the role of annual grasses and shrubs in nutrient cycling of Great Basin plant communities. The study site is a degraded *Artemisia tridentata* community invaded by *Bromus tectorum* and other annuals, and is located on a bench slope near Tremonton in northern Utah. An irrigation treatment was applied during the spring to assess vegetational response the following year. Data from initial samples indicate that *B. tectorum* biomass was significantly higher in the shrub understory habitat than in the open interspaces. Nitrogen content of the grass, however, was higher in the interspaces. Soil nitrogen decreased with depth and distance from the shrub canopy.

A methodological study was conducted by Goodall to examine methods of estimating seed reserves in desert soils. Work in 1971 was chiefly confined to the Curlew Valley validation site. Results showed that a satisfactory separation of all species of seed tested could be obtained with concentrated potassium carbonate solution as the flotation liquid. Species differed greatly in the depth of seed distribution, some having a peak at or just below the surface, while others were still abundant below 5 cm. Much higher seed densities were found beneath the canopies of shrubs and of tussock grasses than in the interspaces. There were no consistent differences, however, associated with the species of the canopy plant or with distance from its center. Tentative estimates of seed populations vary widely with species -- from 4800/m^2 for *Atriplex confertifolia* to 10/m^2 for *Poa nevadensis*. There was no evident correlation between species abundance and seed populations; no seeds of *Artemisia tridentata*, for example, were found in areas where it forms a large component of the vegetation.

INVERTEBRATES

Bender, G.L., J. MacMahon and S. Szerlip. Development of techniques for estimating biomass of desert-inhabiting invertebrate animals.

Hsiao, T.S., and R.L. Kirkland. Demographic studies of sagebrush insects as functions of various environmental factors.

Mankau, R., and S.A. Sher. Biology of nematodes in desert ecosystems.

Nutting W.L., M.I. Haverty, J.P. LaFage and R.V. Carr. Colony characteristics of termites as related to population density and habitat.

Werner, F.G., and S.L. Murray. Demography, foraging activity of leaf-cutter ants, *Acromyrmex versicolor* in relation to colony size and location, season, vegetation, and temperature.

Whitford, W.G., and G. Ettershank. Demography and role of herbivorous ants in a desert ecosystem as functions of vegetation, soil and climate variables.

Coordinator: F. Werner

Except for a methodological study on nematodes, 1971 invertebrate projects concentrated on arthropods, with emphasis on ants.

Sampling arthropod populations is a requisite part of validation site measurements. Following their testing of the D-Vac technique for sampling shrubs, in 1971 Bender and MacMahon pursued a methodological study to assess sampling techniques for invertebrates living in the soil. Soil samples were taken at varying distances from the bases of selected shrub species (*Larrea divaricata, Acacia* sp. and *Prosopis juliflora*). The samples were extracted by the Salt-Hollick flotation technique and the Tullgren Funnel technique, and the methods compared. In every case, extraction by flotation yielded significantly higher numbers of organisms than extraction by the Tullgren funnel method, and the former is recommended for use by validation study investigators. The difference in effectiveness was often a factor of more than 2 to 1 in favor of flotation. A comparision between soil samples to different depths indicated that most desert arthropods live in the top 5 cm of the soil profile. Radial sampling from the bases of selected plants revealed that arthropods are distributed in relation to the shrub dispersion patterns. Sampling more than two radii from the base of a shrub did not appear productive in terms of the numbers of organisms obtained.

The demography and foraging activity of leaf-cutter ants, *Acromyrmex versicolor,* was studied at Santa Rita by Werner and Murray. Surface activity was monitored in relation to weather, soil, and plant cover variables on a 0.36 ha plot of undisturbed vegetation by visual observation at colony entrances at weekly intervals for the duration of the daily activity period. During the extremely dry June, some colonies foraged at night, with peak numbers near dawn when the temperature was minimal. Rainy weather and cloud cover changed this pattern dramatically, so that intense foraging activity followed rain events and alates left the nests during the summer rainy season. As temperatures fell later in the season, foraging became diurnal and on a cool day it ceased altogether. Fresh-cut plant parts were the main material foraged; 25 to 75% of the workers returned to the nest with nothing, however. *Prosopis juliflora* was the most popular plant foraged (whole leaflets taken), while *Circidium microphyllum* and *Acacia greggi* proved consistent sources of fresh-cut leaflets. The tender new shoots of various grasses were heavily foraged at the start of the rainy season, and two prostrate annuals (*Allonia incarnata* and *Euphorbia melandenia*) were taken in their entirety as fresh-cut material. Whether fresh or dry, flower parts of all species were a popular choice. During the course of the study, observations were made on flights of alates, colony maturation and activity, and two colonies were partially excavated.

Density of harvester ant colonies at Jornada was found to be a function of numbers of species of harvester ants in an area and the percent plant cover divided by the number of plant species. Whitford and Ettershank suggest that this is due to selective foraging behaviour of harvester ant species and intra- and inter-specific interactions. In their study of environmental factors regulating harvester ant activity, the authors measured foraging activity as a function of soil surface temperature, humidity near the soil surface, light intensity and food availability. *Novomessor cockerelli* was active at soil surface temperatures between 18 and 33°C, and at saturation deficits between 0 and 30 gm/m^3. *Pogonomyrmex rugosus*, on the other hand, extends its activity up to 47°C and 52 gm/m^3 saturation deficit. Mark-recapture estimates of forager populations of *P. rugosus* demonstrated that forager population size of a colony in this species is variable, averaging 500-5000 individuals. The social dynamics of harvester ants was examined with an imposed mortality treatment. Preliminary results indicate that predation on foragers could have important effects on colony survival, particularly with smaller colonies. Foraging range of *P. rugosus* was determined as intense activity up to 15 m from the colony in an area with harvester ant colony density at 18/ha.

Ecological and demographic studies of termites by Nutting et al. in the Sonoran desert were concerned with the determination of colony size, composition, distribution, density, growth and development of at least one dry-wood and one subterranean species. Four dry-wood and six subterranean species are known from the Santa Rita and Silverbell areas near Tucson. Population and biomass were estimated for three species as follows: *Pterotermes occidentis* (dry-wood), 4.8 colonies/ha, 104.2 termites/ha or 0.48 g/ha; *Heterotermes aureus* (subterranean), 140.7 foraging groups/ha, 23,770 foragers/ha or 8.2 g/ha; *Gnathamitermes perplexus* (subterranean), 705,200 foragers/ha or 374.3 g/ha. *P. occidentis* colonies were found in *Cercidium microphyllum, C. floridum* and *Olneya tesota;* the numbers recorded may be very low, since mature colonies are known to reach at least 2000 individuals. *Heterotermes* feed on a wide range of host plants -- 18 were noted in the present study. Seasonal and daily foraging activity of subterranean species is being analyzed through a novel approach employing toilet paper rolls set out on a meter-square grid on 100 m^2 plots. The rolls act as food units and the method promises to yield instructive data when this experiment is completed. Preliminary results indicate that foraging of *Heterotermes* is limited by upper soil temperatures between 8 and 35°C; moisture regime is a less important habitat factor than soil temperature. Dead wood sampling indicated that there are 2,082 kg/ha of fallen dead wood at Santa Rita, produced at the rate of 718 kg/ha/yr. Standing dead wood on the site amounted to 1,005 kg/ha and appeared at the rate of ca. 262 kg/ha/yr. There was obviously a large accumulation of dead plant material which is not consumed by termites.

Seasonal history, population density and natural mortality of the sagebrush defoliator were investigated at the Curlew Valley study site by Hsiao and Kirkland. The defoliator, *Aroga websteri*, has one generation per year and overwinters as 2nd or 3rd instar larvae. Activity of the species is limited to the months of April to October. The population density at the study site was estimated to be 5-13 defoliators per plant (*Artemisia tridentata*) or 1.6×10^5 to 3.9×10^5 defoliators per hectare. Biomass of the defoliator was calculated at 1.183 kg dry wt./ha. Extrinsic factors accounted for 63% of mortality of the insect. The larval and pupal stages were attacked by 10 Hymenoptera parasites, one Coleoptera predator and one microbial pathogen. Methods were developed during the course of the study for accurate population sampling of the defoliator and estimation of impacts of defoliators on sagebrush defoliation. The latter method has not yet been used as a study technique.

A methodological study on soil nematodes was undertaken by Mankau and Sher. The nematodes were extracted from soil largely by the Cobb sieve-decanting technique after moistening and incubating the soil samples for a few days to a few weeks. Several hundred permanent slides were prepared, but the bulk of the extracted and fixed nematodes have not yet been processed. At this stage, faunistic lists have been prepared for the Colorado, Mohave and Amargosa deserts, and for ecological niches within these areas. The nematode fauna associated with the rhizospheres of dominant plant species have been characterized and special emphasis placed on identifying plant-parasitic species.

VERTEBRATES

Anderson, R.D., and D.F. Balph. An evaluation of trap stimulus in relation to probability of rodent capture.

Balda, R.P., G.C. Bateman and T.A. Vaughn. Diets, food preferences, and reproductive cycles of some desert rodents.

Hungerford, C.R., C.H. Lowe and J.P. Gray. Population studies of desert cottontail (*Sylvilagus auduboni*), black-tailed jackrabbit (*Lepus californicus*) and Allen's jackrabbit (*Lepus alleni*) in the Sonoran desert.

Jorgensen, C.D., H.D. Smith and D.T. Scott. Evaluation of techniques for estimating population sizes of desert rodents.

Saul, W.E. Food habits of northern rodents and jackrabbits.

Schreiber, R.K., and D.R. Johnson. Ingestion rates, live weight caloric densities and standing crop estimates for Desert Biome rodents.

Smith, E.L., and G.T. Austin. Studies on birds.

Smith, H.D., and C.D. Jorgensen. Demographic and individual growth studies for *Dipodomys microps*, *Dipodomys ordii*, and *Peromyscus maniculatus*.

Coordinator: R.M. Chew

Trapping, demographic, dietary and growth studies were conducted on rodents and lagomorphs during 1971. A bird study undertaken at Silverbell was incorporated into the validation report for that site.

Anderson and Balph conducted two methodolical experiments in Curlew Valley to examine the relationship between number of traps per station and the probability of capture of two abundant nocturnal rodents -- *Peromyscus maniculatus* and *Perognathus parvus*. The first experiment tested the hypothesis that probability of capture is in some way increased at multiple trap stations. Preliminary results indicated that the important factor in increasing capture success was the availability of a second trap entrance, rather than the increased stimulus value of a second trap. The second experiment tested a set of hypotheses concerning the effect of a captured animal at a multiple trap station on the probability of subsequent captures. Preliminary results indicated no effect on overall probability of capture. There was, however, a significant relationship between age and state (alive or dead) of the test animal and the age ratios of subsequent captures. *Peromyscus maniculatus* appears to have an age-specific aversion to approaching traps that contain live animals, significant among the juveniles. The differential response in this species is also related to age of the test animal. There was a decrease in the juvenile:adult ratio of captured animals when the test animal was juvenile, independent of state of the test animal. There also appeared to be an increase in probability of capture when the test animal was a dead juvenile.

Jorgensen et al. undertook and completed a theoretical study to develop a field design and subsequent analyses that complement each other so that confounding of the trapping variables of small mammals are reduced and appropriately partitioned. Particular concern centered around the population variables dispersion, death rate, trap avoidance and animal-trap relationships. Lack of breakdown of the "mortality" variable in estimators developed by other workers was deemed to reduce the validity of their estimates. The present study attempted a partitioning, based on stochastic procedures, and written into a computer program, of the one "mortality" function into dispersal, trap avoidance and death rate. A major assumption was that capture-recapture techniques are more favorable in desert areas than kill-trapping.

The initial estimator designed in this project was limited by assumptions that require animals to move from the dense line onto the grid before behavioral parameters such as dispersal and trap avoidance could be partitioned. A more robust revised model provides estimates of mortality, trap avoidance, dispersal and population density, when the dense line yields no information. This estimator was tested with a computer-programmed simulator in 21 experiments, and the estimates of a range of population parameters compared with the estimates of other workers in this field. For most parameters, the revised model proved to be more reliable than other estimators.

In another study, Smith and Jorgensen endeavoured to determine growth rates, natality and mortality for *Dipodomys microps, D. ordii* and *Peromyscus maniculatus,* and determine how these respond to independent variables in natural conditions. In addition, a submodel was planned to use the data obtained to describe the demography of the three species and provide predictive capabilities. Though field enclosures have been constructed and the experiments initiated, there is insufficient data on all but one of the stated objectives to warrant reporting at this stage. Lack of a large enough field population has eliminated *D. microps* from the demographic studies. Natality and mortality figures are not yet adequate for the construction of life tables. Lack of pregnant field-caught *Dipodomys* species has hindered growth studies, but growth of *P. maniculatus* has been characterized by different parameters, distributions and combinations of distributions.

In the Sonoran desert at the Silverbell site, Hungerford, Lowe and Gray have conducted demographic studies on three rabbits -- *Lepus alleni, L. californicus* and *Sylvilagus audubonii.* Monthly censuses were taken along transects and samples of each species collected per month for anatomical examinations such as lens weight, epiphyseal cartilage and reproductive organs. A total of 395 rabbits were collected. The sex ratio of all animals collected did not vary significantly from the expected 50:50. Data on reproductive organs have not yet been analyzed. The maximum General Fertility Rate for *L. alleni* appeared to be in July. Persistence of breeding by *Lepus* spp. into October and November -- an observation not previously noted in the literature -- may be attributed to good summer and early fall rains. Though life tables have not been completed, an evident trend shows an increased percentage of juveniles in the November and December samples. Adult females were slightly heavier than adult males, but 60% of all adult females collected were pregnant. High mortality of litters removed by cesarean section restricted the growth study to one *L. alleni* female. Monthly census data using a strip-transect technique were highly variable and possibly inaccurate. Nevertheless, population distribution appeared to be affected by a combination of rainfall following drought, along with site manipulation. The disturbed areas were found to attract lagomorphs, particularly *Lepus* species, after summer rains had produced new growth of invading plants.

Rodent species studied by Schreiber and Johnson to determine ingestion rates, live weight caloric densities and standing crop estimates, were *Perognathus parvus*, *Peromyscus maniculatus*, *Onychomys leucogaster*, *Reithrodontomys megalotis*, *Dipodomys ordii*, *D. microps*, and *Eutamias minimus*. The rodents were collected from Hanford Reservation (Washington), Curlew Valley (Utah) and southwest of Mountain Home (Idaho). Assimilation efficiencies were determined directly in the laboratory and by the ash tracer method in the field. There was little seasonal variation in the assimilation rates, or between wild and laboratory determinations. Efficiencies ranged from 80 to 97%. It was evident from energy determinations of stomach contents that least chipmunks (*E. minimus*) use saltbush seeds in the fall, and that herbivores subsisted on food of lower energy value than that utilized by omnivores such as deer mice, grasshopper mice, western harvest mice, and least chipmunks. Ingestion rates in Kcal/yr and Kg/yr were calculated for four species. The estimations ranged from 2,846 (*P. parvus*) to 5,425 (*P. maniculatus*) in Kcal/yr, and from 0.503 (*P. parvus*) to 1.225 (*O. leucogaster*) in Kg/yr. Values for *R. megalotis* were intermediate. The ash, water, lean dry, and fat contents of rodent carcasses were determined. Ash contents were remarkably stable (3-4% of live weight). Body water varied, particularly with reproductive state of females. Lean dry and fat portions comprised 20 to 25% of body weight, with the fat component ranging from 2.4 to 5.4% of body weight. The caloric value of the lean dry carcass fell between 5.41 and 5.74 Kcal/gm. Live weight caloric densities ranged from 1.4 to 1.8 Kcal/gm, and the total standing crop of rodents in sagebrush habitats of Curlew Valley was estimated at 0.5 to 1.0 mcal/ha.

Working on the Silverbell site, Balda et al. carried out a study to identify the diets of five desert rodent species and relate the diets to rodent reproduction and desert food resources. Species involved were *Perognathus amplus*, *Dipodomys merriami*, *Perognathus penicillatus*, *P. baileyi* and *Peromyscus eremicus*. Observations of phenological events were made on the site, soil samples were collected and seeds extracted, and at each capture site the vegetation was sampled using the line-intercept method. Diets and food preferences were examined by a microscopic technique yielding relative frequencies of the dietary constituents. Body measurements were made on captured animals and reproductive organs examined. Since June, 1970, 4,103 rodents representing 10 species have been taken. The five most abundant are listed above in order of abundance.

Limited analyses have been performed on the vegetative data. There was a definite seasonal response to the usual bimodal rain pattern of the Sonoran desert, with a burst of plant growth in October, November and December, and another in April, May and June. In 1971, the spring rains failed to materialize. Seed content in the soil surface 2 cm varied considerably (2291 - $125/m^2$), probably due to relative preferences of rodents at different times of the year and activities of harvester ants. Dietary studies indicated that seeds of desert annuals, taken primarily from the surface soil, were by far the most important rodent food, *Plantago* being the most heavily utilized. Excepting *Larrea*, large perennials were of little importance. The rodents were highly selective, almost ignoring a common *Festuca* on the site. Differences between pouch and stomach contents indicated that soft seeds are eaten immediately while hard seeds are stored. Insects made up from 8 to 29% of the diets of heteromyids. The seasonal activity cycles of the most abundant rodents are partially out of phase. The pocket mice were active throughout the warm part of the year but remained below ground in the winter. On the other hand, the kangaroo rat was relatively inactive above ground in hot months but was active in the winter. Body weights fluctuate seasonally. There were two definite reproductive periods in *D. merriami* and, to a lesser extent, in *P. baileyi*. The other three species had one reproductive period of varying lengths in spring and early summer. The smaller species had shorter breeding periods and larger litters.

In another dietary study, Saul examined the food habits of northern rodents and jackrabbits (*Dipodomys*, *Perognathus*, *Peromyscus*, *Eutamias*, and *Lepus*). Stomach contents collected in the field were ground in a Wiley mill to achieve constant particle size, and examined microscopically. Some problems associated with this technique are the difficulty of distinguishing between some grass species and the occasional occurrences of mildew on some plant portions which may reduce the accuracy of species identification. Extensive testing was required before the method was satisfactory and identifications reliable. Samples were obtained from rodents in Curlew Valley on a grass-shrub site. Though the results are still being analysed, certain trends are evident from the data. Quite light use is made of the major shrubs in the area: *Artemisia tridentata, Sarcobatus vermiculatus* and *Atriplex confertifolia*. These species appear to act as "fillers" in the diet, since largely second-year wood is being taken. Grasses predominate in the stomachs of rodents killed near grass seedings. There appears to be no limit to the amount of *Halogeton* an individual can eat. Surprisingly little use is made of *Lepidium perfoliatum* in the diet, while heavy and locally intense use of minor shrubs is evident. Important species in the latter category are *Kochia americana* and *Chrysothamnus viscidiflorus*.

AQUATIC VALIDATION STUDIES

Deep Creek, Curlew Valley, Utah	Coordinator: G.W. Minshall
Locomotive Springs, Curlew Valley, Utah	Coordinator: J.A. Holman
Saratoga Springs, California	Coordinator: J. Deacon
Jornada Playa, New Mexico	Coordinator: C.R. Ward

DEEP CREEK, CURLEW VALLEY

One of the main purposes of the study was to characterize an entire desert stream ecosystem as to biotic community, and the environmental conditions affecting the community. Four sampling stations were established, one in each of the main physiographic sections of Deep Creek. The most important natural factors influencing the stream are annual differences in solar radiation, temperature extremes, and runoff patterns. The stream is also affected by regulation of stream discharge (reservoirs and irrigation withdrawals) and use of the watershed by cattle.

The most outstanding event to occur during 1971 was the March flood which drastically altered conditions at Stations 1 and 2. Two reservoirs dampened the effects of the flood waters on Stations 3 and 4. Turbidity at the various stations was related not only to the flood and increased discharges of water but, during the year, to presence of cattle along the stream and decreases in the amount of aquatic macrophytes. Water temperature, which was suddenly lowered by the flood waters from melting snow, usually ranged from freezing in the winter to 25°C in the summer.

Benthic invertebrates were extensively sampled. At Station 1 there appeared to be 3 times more invertebrates in riffles as compared to reach areas. These numbers attained a peak in August in the riffles whereas in the reach areas of the stream peak numbers appeared during January. The four most abundant (densities greater than 5000/m^2) at Station 1 were chironomids, *Hyalella azteca, Simulium* sp. and *Baetis tricaudatus*. All were found in greater density in the riffles, with chironomids dominating in both areas. At Stations 2 and 3 predominant species diversity increased, but dropped down for Station 4. Throughout the stream *Hyalella* and chironomids were abundant. A length-frequency histogram for *Hyalella* indicated that recruitment from young probably occurred in August with juveniles overwintering to become adults in spring. Average standing crops, production, and turnover rates were calculated for the major invertebrates.

Of the five fish species collected in the stream, *Rhinichthyes osculus* is the most important. Numbers and dry weights were recorded for this species for each station. These data showed recruitment from reproduction as beginning in June.

Sampling and calculations were made to estimate the amount of allochthonous matter added to stream by cattle use of the area. Spring runoff caused much of their fecal material to reach the stream. Dissolved organic carbon recorded at Stations 1 and 4 respectively were 461.3 g/m^3 and 483.4 g/m^3.

Periphyton and macrophyte concentrations differed at each station, with macrophyte biomass reaching the highest levels during the summer in upstream stations. There was a drastic reduction of this level after the annual introduction of cattle into the area in August. The dominant species of macrophytes were *Chara, Eleocharis* and two species of *Potamogeton*. Community metabolism measurements were made on the macrophytes. The results indicated that carbon, rather than phosphorus or nitrogen, appeared to be the main limiting factor during the growth season in Deep Creek.

LOCOMOTIVE SPRINGS, CURLEW VALLEY

Abiotic and biotic parameters and constituents of Off Spring, one of the Locomotive Springs group, have been monitored and sampled from March, 1970, to December, 1971. Similar measurements were made on the Spring out-flow channel during 1971.

A spectacular decrease (from 8.66 to 0.35 gm/m^2) in filamentous algae (*Cladophoca, Spirogyra*) was noted during the 1971 growth season. There were also large reductions in numbers of *Hyalella azteca* (179 to 1/1), Copepods (1554 to 120/1). Uniform and similar levels of dissolved nutrients and temperatures cannot explain these differences. However, the population of Utah Chub (*Gila atraria*) had risen from 360 in June, 1970, to an estimated 15,000 in October, 1971 -- probably reflecting high reproductive success in 1970 when there was an excess of food and cover (filamentous algae). The estimated population of chub had dropped to 2000 by December. Sampling will continue to monitor the return of the algae or possibly an equilibrium set-up between vegetation and fish numbers.

With very low concentrations of dissolved nutrients the possibility of nutrient recycling within vegetative materials is of importance. In order to clarify this situation, three methods were used to estimate bacterial biomass and activity; total plate count, uptake of glucose C^{14} and the kinetics of glucose uptake. Most of the work was done on planktonic bacteria, but a few mud and plant material samples were included. These would indicate that far more bacterial activity is occurring on the mud surface and in association with submerged plants and algae than in the open water.

SARATOGA SPRINGS, CALIFORNIA

Biotic and abiotic parameters were measured monthly on Saratoga Spring and adjacent marsh during 1971. An inventory of plant and animal taxa is presented. The marsh presents a unique problem since it holds four major areas based on vegetation and soil types. These areas were sampled for soil invertebrates which were related to associated plant species and time of year collected. Most invertebrates collected were larval forms, and emergence was responsible for the reduction in biomass.

Data collected in 1966-67 for *Cyprinodon nevadensis* was used to construct a length-frequency histogram. These data suggest a growth rate for mature fish of 3 mm per month during the summer. Dramatic shifts in population structure during April and September indicate the influence by recruitment from hatches occurring in February, July and August. Spawning therefore probably occurs over an extended period of time. Life table information has been calculated from these data. This indicated that 50% of the fish of 15 mm live an additional 8-9 months, while the maximum life span after reaching 15 mm is approximately 16-18 months.

When comparing 1971-72 data to 1966-67 data, general trends appear to be the same with some differences in population peaks and sizes. In September 1971 the population was estimated to be 1600 fish.

Separate sections of this report were devoted to descriptions of amphibia, reptiles, birds, and mammals recorded in the Spring area at various times. The most abundant reptiles appeared to be *Uta stansburiana*, *Cnemidphorus tigris*, *Callisauris draconides* and *Sceloporus magister*. Bird species reported close to the Spring and its vicinity numbered 90, but only 14 species were listed as abundant.

Collections were made in 1967 of small mammals and bats in the Spring and its vicinity. Six species of bats and ten species of rodents were recorded. Distribution, seasonal and reproductive activity, relative abundance, population structure, and food habits are briefly discussed. Most of the species collected were able to maintain maximum population densities in only the more mesic habitats because of the availability of water, food and shelter.

Plant production appeared to reach a peak in May at 47.6 g C/m^2/day with a low in October of 2.6 g C/m^2/day. Aquatic invertebrates except *Hyalella azteca* peak in June, with *Hyalella* peaking early in April.

JORNADA PLAYA

A temporarily flooded desert playa holds a unique group of aquatic invertebrates, most with remarkable rates of reproduction and development. The tadpole shrimp (*Apus*, Notostraca) can appear as half-grown immatures within a week of flooding. The clam shrimp (Conchostraca) can reach maturity in 5 days, and fairy shrimp have a generation time of 7-10 days. Several species of insects have also adapted to these temporary water environments (mosquitoes, beetles and waterbugs.)

Traps were used to sample at six stations. Sampling started July 27, 1970, when the playa filled: by August 14 only the cattle tank contained water. Sampling continued until October 15. A list is given of macroinvertebrates collected. The most important were 5 species of Eubranchiopoda,including tadpole, fairy and clam shrimps, and 17 species of Insecta. The larval forms of at least one of the five species of anurans present were abundant in the waters. A maximum in numbers of clam, tadpole and fairy shrimps was reached on August 3, along with great numbers of aquatic beetles. At this time an algae bloom occurred. As drying occurred huge concentrations of the shrimp and anuran larvae were trapped in potholes of water. This was aided by their habits of feeding in the more tepid vegetated shoreline areas. Numbers of Eubranchiopoda dropped in samples but there was an increase in larval insects with a peak on August 10. Most of these perished in drying potholes long before emergence from pupae was accomplished. The distribution of these invertebrates was related to vegetation density and water depth.

AQUATIC PROCESS STUDIES

Deacon J. Food utilization of *Cyprinodon nevadensis* as a function of availability, age, sex, habitat, temperature and season.

Bradley, W.G. Standing crop and productivity of marsh vegetation at Saratoga Springs.

Kramer, R.H., and P.K. Rajagopal. Respiratory metabolism of Utah Chub, *Gila atraria*.

Gaufin, A.R., J. Stanford, R. Clubb and E. Nisonger. Effects of oxygen and temperature on the survival, growth emergence and respiration of desert aquatic invertebrates.

Hallmark, M.D., and C.R. Ward. The life history and life processes of the Water Scavenger beetle, *Hydrophilus triangularis*.

In a study on food utilization by *Cyprinodon nevadensis*, Deacon found that filamentous algae (*Spirogyra*) appeared to be preferred by the species (52.6-66.2% of gut content), since its occurrence in the gut dropped only when it became unavailable during fall (8.9%) and winter (0.2%). Vascular plants (*Ceratophyllum*) were important in the diet (21.7 + 21.2%) during these periods. Gastropods became significant in the diet only during winter (6.1%) with other benthos becoming significant in spring (22.7%), fall (13.6%) and winter (12.5%). While detritus was important in the diet, it appeared to be relatively unpreferred and is probably an item used as a "filler" when preferred items are in short supply or unavailable.

Feeding periodicity was studied. Results suggest that feeding behavior is stimulated by increasing light intensity at sunrise and by decreasing intensity after the midafternoon peak.

Laboratory feeding experiments were conducted to determine the digestive rate in *C. nevadensis*, using P^{32} labeled rams-horn snails as food. Feeding with periodic sacrifice over 96 hours at approximately 22°C indicated that digestion is essentially completed in 16 hours, with transfer of the P^{32} to the tissues.

The various plant communities surrounding Saratoga Springs were sampled by Bradley for species diversity and average canopy cover. Estimates on standing crop were made by summing the products of average height of each species times its average % cover. Biomass of marsh vegetation was determined by harvest methods.

Data from 1966-67 was included for comparison. Plant communities were described and arranged according to water availability as follows: Xeric Shrub with dominant species of *Larrea divaricata* (creosote bush), *Atriplex hymenelytra* (Desert Holly), and *A. parryi* (Parry's Saltbush); Phreatophyte vegetation with dominants of Salt Cedar, inkweed, *Distichlis spicata* (salt grass) and Honey Mesquite; Salt Marsh Vegetation dominated by *Phragmites* (Reed grass), salt grass complex and *Juncus*.

Soil salinity was measured and found to be highest in the Phreatophyte communities. It is suggested that soil surface salinity limits germination. Salt grass reproducing by vegetative means does well on these highly-saline soils.

Standing crop estimate indices range from 0.89 for the salt flat communities to 95 for the bulrushes. The % area utilized by the various communities ranges from 25% by open water and 23 by salt grass to 1% by tamarisk. Production of annuals was low, not surpassing 0.2% cover during study period. Perennials showed very slow annual growth increments. *Distichlis, Cressa, Phragmites, Scirpus* and *Juncus* made up most of the standing crop biomass in the marsh. A peak of 2833 kg/ha. for green-living parts of all species occurred June through September.

Metabolism and activity index data were obtained by Kramer and Rajagopal for 72 Utah Chub at 6, 9, 12, 18 and 22°C and were related to size of fish. These data are being processed by computer to derive standard metabolic rates.

For each fish a linear regression of activity index (swimming movement during test measured by heat loss) vs. oxygen uptake was calculated. The "a" intercept corresponding to zero activity was taken as the standard oxygen uptake rate. Active metabolism (O_2 uptake) for fish with mean weight of 1.195-1.342 g. increased from 263.29 mg O_2/kg hr at 6°C to 427.62 mg O_2/kg hr at 12°C. For fish with mean weights of 4.968-11.953 g, the O_2 uptake decrease slightly from 760.33 mg O_2/kg hr at 18°C to 665.7 mg O_2/kg hr at 22°C.

Respiratory metabolism data were also obtained for *Rhinichthys osculus* collected from Deep Creek, Curlew Valley. Active rates were measured on fish at 4°, 8°, 12°, 18°C. Standard rates were measured on 17 fish at 12° and 18°C. These data are now being processed.

Investigations were made by Gaufin et al. into the effects of minimal dissolved oxygen concentrations and high temperatures on survival, growth, emergence and respiration of four species of aquatic invertebrates. Oxygen concentrations ranged from 1.0-6.0 mg/l for periods of 24 hours to 30 days. Temperatures ranged up to 37°C. Species used were: *Gammarus limnaeus* (amphipod), *Hydropsyche occidentalis* (caddis fly), *Enallagma anna* (damselfly), and *Argia vivida* (damselfly). *Gammarus* proved to be most sensitive both to reduced oxygen concentrations and high temperature.

Respiration rates for these species showed great variations depending on size, activity and behavior while in the respirometer and temperature of water. Periods of inactivity produced oxygen consumption levels too low to be recorded by the instrumentation used.

The life history and energy budget of *Hydrophilus triangularis* was fully described by Hallmark and Ward. The three larvae instars require 2-3 days and 12-16 days with the length of the third dependent on food availability. Pupation required 10 days and was successful only when appropriate substrate was supplied in the laboratory. If this was not available, mortality at this stage was high.

Egg-laying appeared to be under the influence of atmospheric conditions with the females laying eggs every 2 weeks when there was sufficient water coming into the playa. A maximum of four egg cases may be laid by a female over a 2-month period. There were 53-170 eggs per case.

A life table was formed. Crowding did not noticeably effect mortality at the different stages. The highest mortality was found in the 3rd instar, but was probably due to unsuitable conditions for pupation.

Respiration was measured and found to vary for each instar. A rise was noted towards the end of each instar.

Food habits were studied. Larvae are carnivorous and cannabalistic while the adults are omnivorous, eating fresh and decaying plant matter as well as living and dead animal material.

Amounts of food ingested were measured for the various stages. A ten-fold increase during larval stages was noted with a leveling off to the 3rd instar. A similar curve was noted for respiration. Respiration and growth measurements were used to calculate assimilation, and the growth efficiency calculated for each instar. The second instar appeared to be the most efficient in growth and assimilation (80% of ingested food converted to body weight). Caloric values, carbon and nitrogen levels were recorded for all stages of the beetle plus its exuvia.