1975

Prospectus and Budget for 1976 Program

U.S. International Biological Program

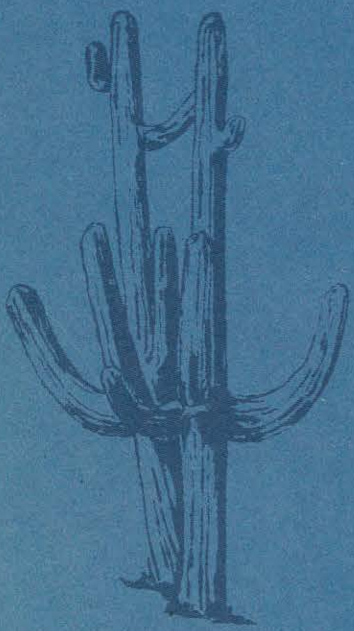
IBP

DESERT BIOME

ECOSYSTEM ANALYSIS STUDIES
U.S. INTERNATIONAL BIOLOGICAL PROGRAM

PROSPECTUS AND BUDGET FOR 1976 PROGRAM

SEPTEMBER 1975



Ecology Center, Utah State University, Logan, Utah 84322

IBP

DESERT BIOME

US/IBP ANALYSIS OF ECOSYSTEMS

September 29, 1975

Dr. Paul G. Risser, Program Director
Ecosystem Analysis Program
Division of Biology and Medical Sciences
National Science Foundation
Washington, D.C. 20550

Dear Dr. Risser:

This letter accompanies 12 copies of a prospectus of research planned for the U.S. Desert Biome in calendar 1976. The prospectus is accompanied by (bound with) a detailed budget for the 1976 research year.

The research outlined in the prospectus differs substantially from the 1976 effort outlined in the Biome's approved 3-year proposal, submitted in 1973, and covering the calendar years of 1974-76. The departure was made necessary by the Foundation's decision to phase out the Biome field research programs by the end of 1976, and to reduce budgets in 1975 and 1976. The resultant 1976 program presented herewith is substantially smaller than originally proposed by virtue of a 20 percent budget reduction, and the reprogramming of funds into synthesis activities now needed sooner than anticipated in 1973.

Some amplification on the matter of synthesis may be in order. Explicitly, about 20 percent of the budget has been allocated to synthesis. But we look on modeling, which is budgeted for roughly 5 percent of the total, as a form of synthesis. And since validation-site and process-study personnel as well as central-administration and data-processing staffs will be participating in synthesis activities, the actual proportion of the program devoted to synthesis will be well in excess of 20 percent, perhaps approximately half.

The prospectus and budget are accompanied by 12 sets of the latest, two-volume progress reports, and 12 copies of the 1974-76 proposal for the convenience of reviewers.

ECOLOGY CENTER – UTAH STATE UNIVERSITY – LOGAN, UTAH 84322

If any further information is needed, we will be happy to supply it promptly.

Sincerely,

Frederic H. Wagner
Director

FHW:jn
cc: Executive Committee

Concurrence:

M. K. Jeppesen
Contracts Officer

U.S. DESERT BIOME PROGRAM

Analysis of Structure and Function of Desert Ecosystems

PROSPECTUS OF THE 1976 PROGRAM

Submitted to the National Science Foundation, Ecosystems Analysis Program, in conjunction with a detailed budget, two progress-report volumes, and the 1974-76 proposal.

Ecology Center
Utah State University
Logan, Utah

September, 1975

INTRODUCTION

This document is a prospectus of the research program planned for the U.S. Desert Biome in calendar 1976, along with a detailed budget for that program. The 3-year (1974-76) proposal submitted to the National Science Foundation in 1973 (and duly approved) described the program for each of the 3 years in some detail. At the time that proposal was prepared, the policy indications were for continuation of the program into the late 1970's. A budget was prepared for approximately level funding and field research through 1976, and a rather limited effort (11 percent of the total) committed to synthesis.

With the policy developed in 1974 for funding reduction in 1975 and 1976, and complete cessation of field research by the end of 1976, the 1976 program outlined herein is quite different from that set forth in the 3-year proposal. The 1975 program proceeded with a sizable ($50,000) increase over 1974 in funds budgeted for synthesis, absorbed a $100,000 reduction, and still maintained a field-research program not too much smaller than that of 1974. The currently proposed 1976 effort would commit 20 percent of the total to synthesis and reduce the total budget by $200,000, all by substantially reducing the field research and administrative aspects of the program (Table 1).

With one exception, the field-research projects proposed for 1976 are the terminal efforts on studies that have been underway anywhere from 1 to several years. In each case, these projects are key studies which fall into the major objective areas of the program: carbon flow, nitrogen cycling, and water processes. They will concentrate either on important knowledge gaps, the filling of which will complete the elucidation of important topics, or on provision of specific data needed by the simulation modeling activities.

Table 1. Individual Project Budgets Programmed in 1974 and 1975 and Proposed for 1976.

Budget Item	1974	1975	1976 Proposed
CENTRAL OFFICE			
Management and Administration	211,890	196,710	174,952
Data Processing and Retrieval	118,193	103,980	90,607
Modeling	214,484	173,921	121,072
	544,567	474,611	386,631
VALIDATION			
Chemical Analyses	19,640	17,295	13,280
Curlew Valley	76,986	76,986	67,830
Rock Valley	78,000	78,741	67,081
Tucson Basin	72,495	71,855	61,632
Jornada Experimental Range	84,475	84,483	75,967
Pine Valley	14,066	14,065	15,265
	345,662	343,425	300,655
PROCESS STUDIES			
Plants			
Coordinator	2,000	1,540	-
Bamberg (Wallace) - productivity	21,833	26,368	26,022
Caldwell - carbon balance	26,874	28,979	28,778
Szarek - gas exchange	5,632	12,479	15,393
Cunningham - carbon balance	17,785	27,239	12,890
Patten - Sonoran annuals	10,321	7,627	-
Whitson - Chihuahuan annuals	16,350	16,649	-
Klikoff - Great Basin annuals	14,550	7,523	-
Romney and Wallace - H_2O and N_2 constraints	11,480	11,885	11,919
Norton - carbon loss	7,075	8,032	
MacMahon and Norton - H_2O and herbivory	16,390	16,432	16,432
Klemmedson - N_2 distribution	3,435	-	-
Jurinak - N_2 and P constraints	12,140	12,200	-
	165,865	176,953	111,434

Budget Item	1974	1975	1976 Proposed
Vertebrates			
Chew - Perognathus density effects	10,371	1,330	-
Soholt - rodent effects on plants	13,294	10,643	-
Brown - rodent and ant granivory	17,259	11,101	11,862
Dingman - pocket gophers	7,180	-	-
Reichman - rodent granivory	5,680	10,399	6,734
Whitford - granivory effects on vegetation	13,000	14,114	11,999
Balph - Curlew Valley rodent foods	-	6,285	6,735
Pulliam - avian granivory	-	-	13,661
	66,784	53,872	50,991
Invertebrates			
Sferra - soil invertebrates	15,152	3,000	-
Hsiao - sagebrush defoliator	12,912	10,302	-
Nutting - termite bioenergetics	21,571	15,957	4,830
Whitford - stem girdlers	12,370	-	-
Edney- soil micro-arthropods	15,131	17,998	-
Mankau - nematodes	17,967	18,422	16,318
McBrayer - soil micro-arthropods	14,512	-	-
Whitford - ants	3,924	-	-
	113,539	65,679	21,148
Microbial/Nutrient Cycling			
Skujins - N_2 dynamics	25,800	25,580	25,200
Wallace and Romney - N_2 tranformations	11,952	12,671	12,373
Staffeldt - mycorrhizae	13,036	12,953	-
Farnsworth - N_2 fixation	10,920	10,920	-
Skujins - N_2 retention	11,120	10,182	-
Comanor - decomposition	11,164	10,381	-
O'Brien - decomposition	3,039	-	-
Tucker - denitrification	8,000	-	-
	95,031	82,687	37,573
Abiotic: Water Dynamics			
Evans and Qashu - infiltration	15,524)		
Qashu and Evans - soil-water movement	9,600)	35,400	35,415
Evans - lysimeter	16,204)		
Stolzy - soil-water flow	12,978	13,391	-
Cable - plant water extraction	3,168	2,005	
Campbell - water uptake	8,278	-	-
	65,752	50,796	35,415

Budget Item	1974	1975	1976 Proposed
Aquatic			
Coordinator	1,200	1,200	-
Minshall - benthic organisms	20,000	11,740	12,047
Wagner - Deep Creek model	-	8,260	8,460
	21,200	21,200	20,507
Process Studies Subtotals	528,171	451,187	277,068
SYNTHESIS			
Non-modeling	12,900	12,970	12,970
Resource Management	47,020	49,936	43,617
Program Synthesis - Utah State University	21,680	67,871	159,913
Program Synthesis - University of Arizona	-	-	6,779
Program Synthesis - Museum of Northern Arizona	-	-	5,711
Program Synthesis - University of California, Riverside	-	-	6,656
	81,600	130,777	235,646
GRAND TOTALS	1,500,000	1,400,000	1,200,000

The synthesis efforts will be oriented toward the development of generalizations about the structure and function of the ecosystems on the five research sites, and on certain general questions of North American deserts. This effort envisages the synthesis of site data by post doctoral personnel added in 1976 and assigned to the sites, and ultimately generalization across sites to characterize the Desert Biome on this continent.

Modeling efforts in 1976 will continue to finalize models developed according to the two major approaches -- general-purpose and question-oriented -- and to compare the performance of these two modes.

In order to facilitate the remaining field research, the several aspects of synthesis, and the continued modeling effort, a sizable data processing and retrievable program, and central administration will be maintained in 1976.

By the end of 1976, all field research will be brought to a close. Modeling and synthesis will be pressed as far as possible during this year, but it is anticipated that some further effort will be needed. And, depending on the magnitude of the effort remaining, some further funding will be sought for 1977 and perhaps part of 1978.

RESUME OF RESEARCH DESIGN

In brief review, the program was originally designed to analyze the structure and function of U.S. desert ecosystems, and to develop predictive models of those systems. In order to accomplish this goal, three major facets of the effort have been defined. The first is the study of individual processes in individual species which play major roles in the ecosystem function of five representative desert sites (Figure 1). These process studies, annually numbering between 35 and 50, and with 17 scheduled for completion in 1976, have been designed to provide the rate functions for the predictive models. They have been subcontracted to investigators in 15 to 18 universities, and have been selected and designed according to their relevance to the research design for each of the five areas.

The second major facet has been the model development itself. This is carried out by a modeling staff based at Utah State University. A major factor in the success of this undertaking is the close contact and rapport between modelers and field biologists.

The third major facet of the program has been the validation site investigations. The five primary sites (Fig. 1) were chosen to represent the five, major desert types in the United States:

(1) Curlew Valley in the Northern Sagebrush Desert.

(2) Pine Valley in the Salt-desert Shrub type. Sagebrush and salt-desert Shrub types collectively make up the Great Basin or "cold" desert region.

(3) Rock Valley in the Mohave Desert.

(4) Tucson Basin (Silver Bell) in the Sonoran Desert.

(5) Jornada del Muerte Experimental Range in the Chihuahuan Desert.

The models under development are being designed to simulate the ecosystems on these sites. Measurements on the sites were originally designed to provide an extensive list of periodic, state-variable measurements with which : (1) to initialize the state of the system for simulation runs; (2) to provide input measurements, particularly of the physival environmental factors (driving variables), for the model over time; and (3) to provide periodic state-of-the-system measurements against which to compare the simulated values of the model. Site studies, which are carried out by teams

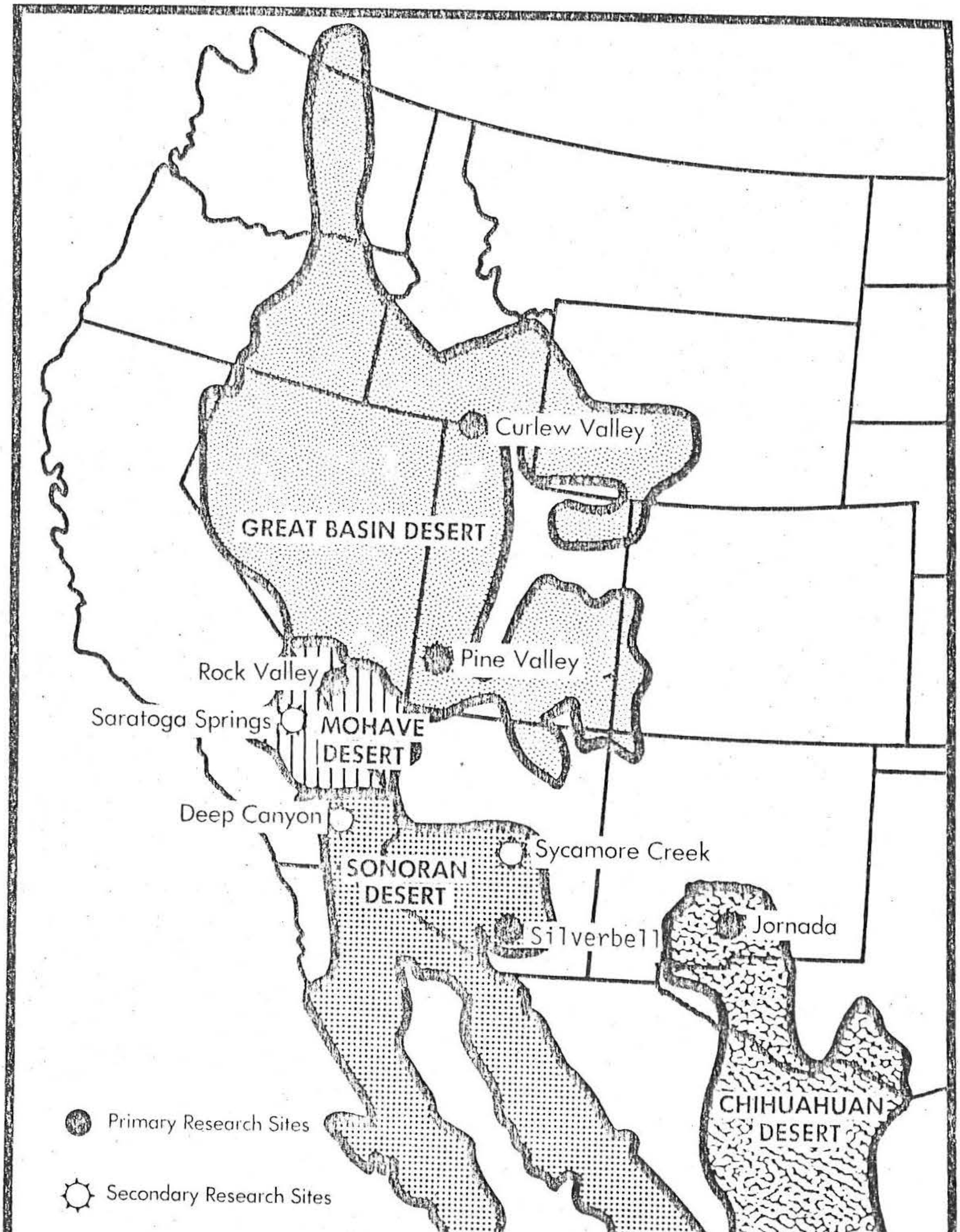


Figure 1. Location of research sites.

of investigators, have been subcontracted to six universities in the vicinities of the sites.

The objectives of model development, and the considerable structuring of the field research around these objectives, still remain as major characteristics of the program. However, the completeness of the measurements on the sites plus the array of process studies provides a data base from which the more traditional generalizations about ecosystem structure and function can be induced. Hence, the development of such generalizations has emerged as a major program objective parallel to the modeling objective. This emergence is more a conceptual and synthetic one than any major change in the operational character of the program. It has become a major framework for the synthesis activities, and is outlined below in the Synthesis section.

The field research and modeling facets of the program are supported by a central administration which provides planning, coordination, and direction; editorial publication, and communication services; and travel support for Biome, national, and international meetings. They are also supported by a data processing, storage, and retrieval function which provides statistical design and analyses for the projects; and makes data available for various synthetic purposes including the modeling activities.

The 15 to 18 institutions which have participated in the program each year have been represented by something on the order of 100 investigators each year.

OUTLINE OF 1976 PROGRAM

Central Office Management and Administration

The major administrative responsibilities of the Biome central organization have changed to a substantial degree in these final years of the program. In prior years the major responsibilities have been (1) to conceptualize meaningful objectives for the program, (2) particularizing these into manageable research projects for individual investigators or groups of researchers, and (3) assure the productivity of these projects. As the program concludes, the major responsibility is now to stimulate and coordinate the synthesis of research results into meaningful generalizations about the structure and function of U.S. desert ecosystems.

This new responsibility requires a central administrative staff of considerable size to continue performing many of the administrative functions performed in the past as well as new ones:

(1) Review and selection of the few remaining research projects.

(2) Maintaining fiscal records connected with the sub-contracting of the latter.

(3) Development of synthesis concepts and hypotheses; and the coordination of these with concepts and hypotheses generated by other scientists in the Biome into a coherent, overall effort.

(4) Provision of editorial typing, and drafting services for reports and publications developing from the effort.

(5) Finance domestic and foreign travel for Biome investigators attending professional meetings, as well as for Biome conferences.

Both as an economy move and because of declining responsibilities, the process-study coordinator positions will all be phased out by 1976. Their remaining responsibilities have been taken over by the directorate in Logan. Nevertheless, the coordinators have been asked to continue on the Biome Executive Committee in an advisory role. Program planning and policy are still reviewed with the Committee during its periodic meetings. This pattern will continue in 1976.

The validation site programs will be reduced in 1976, but these sites and their personnel will be foci in the synthesis efforts. Hence the site coordinators retain sizable responsibility. They continue to serve on the Executive Committee in the same status as in prior years.

Communications with Biome investigators and other interested scientists continue through several media: the annual informational meetings, the Biome newsletter, the Research Memorandum series which constitutes the annual progress reports of all aspects of the program.

Biome participants are strongly encouraged to publish the results of their work in the open literature, and page charges and reprint costs are underwritten.

As a consequence of these functions, the Central Administration will continue to be funded at a substantial level in 1976, although that proposed level is roughly 20 percent below the 1975 level and 25 percent below the 1974 level.

Data Processing and Retrieval

The data processing and retrieval operations will continue at a high level in 1976. While the number of studies -- and therefore the requests of data processing and storage in the data bank -- will be fewer, the synthesis activities will make retrieval and numerical analysis demands on the staff.

In addition, a major 1976 goal will be the editing and "cleaning up" of all data sets preparatory to their storage after the program closes. There are nearly 1,000 such data sets, and with some impetus developing to store the I.B.P. data sets in regional data banks, it is important that these sets be edited, checked for errors, and stored in forms accessible to persons not familiar with the original research. This operation has begun with the Biome data, and some 150 data sets have been checked or groomed for storage. The 1976 objective is to complete this operation.

Modeling

Over the 6-year history of the Desert Biome, those responsible for the modeling effort have pursured two alternative and somewhat conflicting philosophies. Advocates of the first, which has come to be known as the "question-oriented" approach, have eschewed the idea that a large, whole-system model capable of answering a variety of a posteriori questions, could provide realistic and precise simulations of an ecosystem. The extreme of this philosophy consists of an ad hoc approach in which models of limited subsystems are designed as "what-if" questions about those subsystems posed by ecologists or resource managers. Such models may be both unrelated and imcompatible with each other.

The second school holds that whole-ecosystem models are desirable and useful, and that large, generalized models of a system can be developed which then can provide effective answers to a wide range of a posteriori questions. David Goodall, principal advocate of this second approach in the Biome, has further conceived of a modular structure for such a model. In this concept, the total ecosystem model is divided into three submodels:

plants, animals, and soils. Within each of these submodels, interchangeable modules of varying degrees of complexity, mechanism, and resolution can be developed and substituted.

For example, if high-resolution simulations of the plant subsystem are desired, a high-resolution plant module can be inserted in the model structure. If animal and soil processes are of lesser significance, low-resolution modules of these subsystems can be inserted, and simulations of the entire ecosystem run with high-resolution output for the plants and low resolution for the others.

The virtues of this approach are in its computing economy and in the means for scaling down a whole-ecosystem model to the capacity of most computers. The various modules must, of course, all be intercompatible in terms of their inputs and outputs. But within their internal structure, large differences in complexity can be accommodated.

Over the history of the Biome, different individuals in the modeling group have adopted personal positions at different points along the spectrum bounded by the extremes described above. While maintaining the worth of the ad hoc approach in the case of questions about limited subsystems, everyone in the group has agreed over the past 2 or 3 years that the special mission of the Desert Biome, as with the other Biomes, is to explore and simulate the functioning of the whole ecosystem. Consequently, the two groups have worked to develop whole-system models of the desert, the one question-oriented and the other in a modular, general-purpose structure.

By the end of 1975, the question-oriented group will have completed a whole-ecosystem model structured to predict the changes in above-ground primary production that might occur with specified, long-term alteration of precipitation patterns. During 1976, a model will be built which will simulate changes in production consequent upon changes in grazing patterns, and one which will predict the effects on the desert nitrogen cycle resulting from alterations in precipitation and grazing.

During 1974, the most sophisticated submodel versions (Version 4) of the general-purpose model were developed; and the lengthy task of fleshing them out with the input variables for one or more of the validation sites should be largely completed in 1975. When this is completed, it will be possible to ask of this model the same questions as those around which the question-oriented models are being structured. We will then be in a position to compare costs and predictive precision of the two types of models.

Such comparisons are planned for 1976. In addition, some modifications will be made in Versions 2 and 3 of the general-purpose model in order to develop fully the modular structure.

In general, the major contributions to the theory of ecosystem modeling which have developed out of the Desert Biome effort would appear to be two-fold. The first is the Goodall modular or hierarchical structure. The second is the thinking which has precipitated about the relative merits of the question-oriented and general-purpose approaches. This interaction will stimulate the development of explicit criteria by which the worth of models can be judged during 1976.

Full development and documentation of these two approaches, and full exposition of the evaluation of both are accorded major Biome priority for 1976. These efforts will be pursued in 1976 with 21 percent reduction in modeling budget (Table 1).

One other modeling objective for 1976 is completion of the Deep Creek aquatic model structured on the framework of the general-purpose model. Deep

Creek is a small, ephemeral stream in Curlew Valley which has been under investigation since the beginning of the program, and which is now being subjected to light and nutrient perturbations to challenge our understanding of the system.

The model has been adopted with modifications for use in the U.S. Bureau of Reclamation environmental impact study of the Central Utah Water Plan. This Plan is designed to tap water from the north-south streams along the south slope of the Uintah Mountains in eastern Utah, and carry the water by aqueduct to central Utah agricultural and industrial areas. The model is being used to simulate the effects of removal on these streams.

Validation Studies

Chemical Analyses and General Services

A small laboratory has been maintained on the Utah State University campus to provide calorimetric and elemental analyses of plant and animal species on the validation sites, of litter and soil fractions, and of microbial-activity indices. These analyses will be concluded in 1976 with a reduced budget.

Other services such as bibliographic, insect taxonomic, and coordination of aerial photography have been provided by this Biome program. Some additional effort along these lines may be needed in 1976.

Validation Sites

Roles in the Biome.-- The evolving roles of the validation sites were discussed in the Introduction. These were designed initially to provide a wide array of state-variable measurements which would (1) provide initializing values for simulation runs, (2) provide the models with driving-variable inputs over time, and (3) provide real-world measures of the ecosystems at points in time against which the simulated values could be compared.

An important operating principle was the avoidance of circularity. The process studies were designed to provide the rate equations from which the models were to be constructed. The validation measurements were to provide independent state-of-the-system measurements with which to assess model performance. It was important to keep the two separate so that the models could be constructed with one set of observations and tested with another.

However, time and funding limitations have forced some compromise between the pure, idealized distinction between the process (rate) and validation (state) measurements. Time and funds have not permitted intensive process studies on all of the relevant processes in all of the major plant and animal species in all of the five validation sites. At the same time, rates can be estimated from successive state measurements like those made on the validation sites. Consequently, it has been necessary to use some of the site measurements for developing rate estimates with which to structure the models.

An extreme example is the insect situation. A preliminary estimate based on one sampling procedure places the number of insect species on the Curlew Valley site at 637. This is undoubtedly conservative, and the total for the site may eventually settle out at somewhere between 700 and 800.

Obviously, many of these species are present in very low numbers. Their importance in the system in terms of the amount of energy and material moved, or in terms of their control action on the system's function, is likely small. (The latter half of this statement is made somewhat more positively than present knowledge really permits. We do not yet have a confident sense of the importance of numerically minor species in "control actions", either individually or in varying combinations. Any such broad sense is not likely to come very soon through empirical study, but useful hypotheses for the interim might be produced through simulation. Meanwhile, experiments should be pursued wherever possible.)

What might be considered "important" species might include no more than 75 to 100 of the total. Yet to develop sufficient process studies to provide the data on food preferences and consumption rates, bioenergetics, and demography needed for the development of a mechanistic model for even this reduced number is obviously beyond the financial and manpower resources of the Biome. Typically, the invertebrate process studies in the program have numbered between 5 and 10 per year.

The only insect modeling recourse open to us is to adopt a highly empirical, much less analytical, approach based on the validation-site data. These data provide periodic (i.e. anywhere from weekly to monthly) estimates of insect numbers and biomass through the year on the sites. In the case of the herbivorous forms, we can calculate their total metabolic demand on the basis of existing equations which express metabolic rates as functions of body size and ambient temperatures. Combining these calculations with the existing knowledge of assimilation efficiencies in different herbivorous species, we can roughly approximate the amount of herbage consumed. With the further knowledge we have from our sampling on the plant hosts of the species in question, we can roughly prorate the herbage over the plant species on the sites.

This is not a precise approach, but it is the only avenue open to us at this time for developing our first approximations. And order-of-magnitude estimates are very much needed at present to give approximations of the energy and material moved by consumers in the desert system. The impression is growing that primary consumers utilize a very small fraction of the primary production. But this impression is based largely on what we know about vertebrate consumption, with little real feeling for the invertebrate role.

In conclusion of this discussion on the modeling role played by validation measurements, their use for supplying rate measurements now incurs the risk of circularity in their validation function. Obviously to construct and test a model with the same data is a boot-strap operation. Hence, careful attention must be given to this risk in testing the model with the site data, and precautions taken not to use the same data in both construction and testing.

The potential of the validation-site measurements goes substantially beyond the modeling-support roles discussed above. For the complete set of state measurements, along with the physical measurements, over a period of years provides a rich array for heuristic and inductive analyses toward questions of theoretical interest. Some examples include:

(1) Community structure. The site measurements provide a basis for describing desert community structure in terms of species diversity, trophic ratios, species packing, and niche structure.

(2) Variability of the system. The time series from the sites on primary production and animal population densities are yielding a knowledge of the variability of the desert system, and the environmental variables (conspicuously moisture, of course) to which that

variation is keyed. It is already evident that the desert is more variable within the same relative range of moisture variation than grassland or forest, and that within the desert certain components of the system are more variable than others. In some cases causality has been determined or postulated.

The converse or complement of variation is self-regulation or homeostasis, and the site time series provide a basis for analyzing the self-regulatory propensities of desert species according to the sequence of tests beginning with Ricker (1954) and culminating in the recent k- factor analyses (Varley, Gradwell, and Hassell, 1973).

(3) Evidence of biotic interactions. Clues to interactions between environmental factors, both physical and biotic, and ecosystem components are frequently provided by observing correlated variations between the two.

Since physical factors such as weather tend to be highly variable and are more readily measured, this correlative approach is a common one. But the same approach to detecting biotic interrelationships is quite uncommon, mainly because biotic components are more difficult to measure, and time series on more than one component in a system are rather uncommon. The site measurements are a conspicuous exception to this generalization, and should provide clues, often through <u>inverse</u> correlations, to competitive and predatory interactions.

The site measurements tend to be mechanical and routine. Even though delegated to technicians as much as possible, they are not very popular among Biome investigators. Yet one cannot escape the conviction that a long (e.g. 10-15 years), complete time series of the species on the sites would be an invaluable, fertile field for disclosing hitherto unrecognized aspects of desert ecosystem structure and function.

Calendar 1975 was the fifth and last year of complete site measurements. The measurements planned for 1976 will be a limited subset of those made during the past 5 years. And while the collective validation-site budgets will only be reduced by about 13 percent, the field program will in fact be reduced more than this. This reduction will occur because, as discussed below under Synthesis, the sites are being made focal points for synthesis activities. Site personnel are participating, and will participate in 1976, in these activities, and a substantial fraction of the budgets can be considered as prorated to synthesis.

The measurements to be made in 1976 will be a limited set of parameters needed to complete certain series of observations which were either started late and/or have emerged as particularly significant in the structure and function of the systems on those sites. These are outlined below.

Individual sites active in 1976.--

(1) Curlew Valley. The Curlew Valley site in northwestern Utah, representing the sagebrush (*Artemisia tridentata*) vegetation in the Great Basin desert, will continue to be operated by Utah State University investigators. The measurements on this site, along with key process studies, provide one of the most complete pictures we have for any site of carbon balance in the vegetation and primary production, and of the nitrogen cycle.

Because of this completeness, Curlew Valley has been the first site selected for simulation by the models. And despite this completeness, it has been necessary to use some of the validation data to structure the model. Validation will take place with data from the later 2 to 3 years of observations. For this reason, an additional set of data from 1976, even if on a reduced scale, is an urgent need in the program.

In addition to compiling 1 more year of validation data, Curlew Valley site personnel will concentrate on completing specialized studies on litter production, soil invertebrates, and vegetation responses to irrigation; and will participate in synthesis activities. The budget for this final year has been reduced 12 percent below that of 1975.

(2) Pine Valley. The Pine Valley site in southwestern Utah was activated in 1974. This site is representative of the salt-desert shrub vegetation in the Great Basin Desert, and is a plot on the U.S. Forest Service's Desert Experimental Range. It was activated cooperatively with U.S.F.S. in order to integrate with their 40-year research program in this area. Because of their manpower contribution, the limited effort permitted by fund limitations make a viable site effort feasible. The site is operated by Brigham Young University investigators and some input from the Utah State University personnel associated with the Resource Management project described elsewhere in this proposal. The proposed budget for the final year of operation is roughly the same as the 1975 budget.

(3) Rock Valley. This Mohave Desert site, situated within the Atomic Energy Commission's Nevada Test Site, has been operated by investigators from U.C.L.A. and California State College at Long Beach. Like Curlew Valley, the measurements on this site have been quite complete, and Rock Valley has also been selected as one of the early sites to be

modeled. Here again, one more year of validation measurements, even if on a reduced scale, will be most valuable for the modeling needs.

Site personnel propose to concentrate on the following measurements in 1976.

(a) Net primary production by annuals and perennials.

(b) Litter production by six important shrub species.

(c) Estimate of abundance (and likely energy requirements) of detritivorous beetles (primarily Tenebrionids) as revealed by 9-10 months of continuous trapping in a number of $50m^2$ enclosures. This is of particular interest because of the very large populations of these animals crudely estimated by capture-recapture techniques. At the same time, it is desirable to develop a sound picture of these organisms in the carbon- and energy-flow patterns of this system. Investigations in all of the sites are showing that phytophagus organisms are taking a very small (5-10 percent) fraction of the annual, primary production. In the steady state, the plants (whole or part) must be dying and moving into the litter and detritus components of the system. In the other two southern sites (Jornada and Silver Bell), termites are playing a dominant role in consuming this dead plant material. In Rock Valley the indications point to the large beetles, and this hypothesis needs further exploration.

(d) Supporting abiotic measurements involving air temperatures, rainfall, soil water potentials, soil temperatures, relative humidity.

The budget for this site has been reduced 15 percent.

(4) Tucson Basin. The Sonoran Desert site, commonly called the "Silver Bell" site after the name of a nearby mine, is located in Avra Valley northwest of Tucson. It has been operated by University of Arizona investigators.

The technology of making a complete array of state-variable measurements has been most difficult on this site because of the structural complexity of the vegetation. The life forms range from a diverse two-season annual flora to small trees 5 to 8 m. in height, saguaro cacti higher than this in some cases, and virtually untouchable cholla cacti cloaked in dense, virulent spines.

Some of the most effective root measurements, thorough vertebrate investigations, and soil analyses have been made on this site. In addition, some of the most detailed and complex physical environmental measurements have been made with its meteorological station, the most sophisticated of any of the sites.

Yet some aspects of vegetation measurements and the generalized invertebrate measurements have developed slowly because of the sampling problems. As a result, one more year of observations on these aspects of the system will be extremely valuable.

As one contribution to the synthesis efforts, Dr. John Thames, site coordinator, will use existing computer programs to analyze and characterize the physical environmental characteristics of all the sites. In particular soil moisture and temperature regimes, and heat budgets will be compared between the five sites.

The site budget has been reduced by 15 percent.

(5) Jornada. This site occurs in the Chihuahuan Desert of southern New Mexico. Operated by investigators at New Mexico State University, it contains both a terrestrial system and a seasonally flooded playa. As such, it contains a greater diversity of ecological types, and the program here has accordingly been the most diverse of the five sites.

During calendar 1975, work at the Jornada Validation Site was focused on summarizing and preparing for publication the data collected since the initiation of the program in 1969. Examination of the data sets and work on a monograph summarizing our understanding of the structural and functional relationships of the components of a Chihuahuan desert watershed prompted a focus on particular areas where the data base is weak and which appeared crucial to providing even a preliminary basis for understanding the ecological relationships of this system. Consequently, efforts were concentrated on rates of litter production and distribution of litter (horizontal and vertical in the soil), dynamics of soil-surface arthropod populations, and influences of grazing on the stability and productivity of the *Panicum obtusum* community on the playa bottom. Because detailed studies were required in these areas, it was necessary to continue a full set of meteorological measurements on both sites, make measurements of net production of shrubs, forbs and grasses at periods of peak production, and make estimates of vertebrate population numbers twice during the year. These data provided the basis for comparisons with previous years when intensive measurements were made.

During calendar 1976, only those field studies which require additional effort to obtain the data required for publication, plus the minimum set of support measurements, are proposed in order of priority:

The playa and bajada weather stations will be operated continuously recording incoming solar radiation, air temperature and humidity and rainfall intensity and amounts. Soil temperatures at two depths are recorded at each station. Soil moisture and temperature from the network of gypsum resistance blocks will be recorded once per month.

During the 1975 field season, pitfall traps were established within lawn-edging enclosures to obtain quantitative data on soil-surface arthropods by removal trapping. The large 700 m^2 circular enclosures proved to be a feasible method for obtaining quantitative data on soil-surface arthropods. The number of enclosures in 1976 will be doubled or tripled to provide a second year of data and to provide more information on spatial heterogeneity.

Studies to date have documented that most of the net primary production in the system is consumed by detritivores. Studies during 1974 and 1975 on rates of litter production by plant part and species provide a basis for predicting litter production as a function of primary production. In 1975 studies were initiated to determine the spatial (horizontal and vertical) distribution of litter and the effect of termites as detritivores on detritus from different plant species. The litter trap studies will be continued and measurements extended on spatial distribution of litter for another year. In addition to termites, crickets and tenebrionid beetles are likely candidates as important detritivores. The pitfall traps will provide density estimates for these groups, and laboratory and field studies of consumption rates and food preference will be undertaken.

In 1975 the playa site was divided into halves by a fence and subjected to two different grazing intensities to test the hypothesis that intensive grazing and trampling would reduce the cover and viability of the grass

Panicum obtusum which had achieved nearly 100 percent cover after 3 years of protection from grazing. Measurements include rates of consumption by cattle and growth patterns and amounts by *Panicum obtusum*. This work is being conducted via the cooperative efforts of Drs. Reldon Beck and Rex Pieper of the Range Science Department at New Mexico State.

In order to compare data collected in 1976 with data from previous years, a minimum set of state variables must be measured using the same techniques as previous years. These include (1) growth of major shrubs (growth increments of tagged branches), (2) density and biomass of annuals (3) production of perennial forbs and grasses, (4) breeding bird census, (5) pre-breeding rodent and lizard census (early summer), (6) flush transects (arthropods) once per month May through October and (7) spring and fall rabbit census.

In the proposed synthesis plan of the Desert Biome, a measurement of vegetation distribution ($gms \cdot m^{-2}$) at five levels below ground were requested for between-site comparisons. Since such data have been collected only for the playa bottom, the requisite data will be collected at randomly selected points on the playa and bajada sites using whatever standard techniques are proposed by the Biome Directorate.

Another group of measurements proposed for between-site comparisons which have not been made are measurements of (1) leaf-area ratio, (2) green stem-area ratio and (3) chlorophyll per unit area in leaves. These measurements should be taken in February, May, July, September and November to provide estimates of yearly variation in these parameters. They would be made using standard techniques proposed by the Biome Directorate.

The Jornada site budget for this final year will be reduced by 10 percent.

Process Studies

The largest program reduction has been made in the process studies. Numbering between 40 and 50 research projects during the years of highest Biome funding, the projects proposed for 1976 actually number only 16. (One effort which is actually a modeling operation -- completion of the Deep Creek model -- is listed under process studies. And a small termination budget for the long-duration termite studies in Arizona is also included in this block.)

By the same token, the proposed budget for 1976 process studies is only about half the funding level of 3 years previous.

The proposed projects are ones needed to complete certain areas of understanding to which we have committed funds and intensified effort in prior years. These are itemized below.

Plant Studies.

The Biome plant process studies have settled into three major categories, all of which overlap through one or more projects with animal and abiotic process studies. The first of these is a group which might collectively be called carbon-balance studies in perennials. The task of constructing a simulation model of an entire ecosystem requires the selection of some set of processes common to plant, animal, and microbial organisms in the system. These common processes make it possible to view and simulate the system as an integrated unit of components which in other ways (e.g. taxonomic, morphological) are very different.

The most common integrating processes used in ecosystem modeling are those processes involved in flows or exchange, most often of energy or carbon. The vehicle chosen for the Desert Biome is carbon flow, and hence the plant process studies are concerned with those plant processes involving the capture, movement, structuring, and loss of carbon within the vegetation.

In the early years of the program, carbon-balance studies in the perennials concentrated on gas-exchange studies of photosynthesis. Projects in these areas have been carried out under the direction of M. M. Caldwell at Utah State University, Samuel Bamberg of U.C.L.A., Irwin Ting at U.C. Riverside, and Gary Cunningham at New Mexico State University.

As photosynthetic patterns were progressively elaborated in various Great Basin, Mohave, and Chihuahuan shrubs, succulents, and grasses, these studies turned to other aspects of carbon allocation: translocation; organ growth (including flowering, leaf and stem growth, and root growth); respiration; and organ death. We are now approaching our first approximations of the entire carbon balance of perennial plant communities (cf. Caldwell, 1974). Four projects are proposed for conclusion of this general area in 1976: Wallace (formerly Bamberg), Caldwell, Cunningham, and Szarek.

A second major area of plant process studies is that of annual plants. Annuals are a more conspicuous part of the vegetation in deserts than in any other major vegetation type. In fact, the evidence is growing (Fig. 2) that annuals have co-evolved with perennials to become a major climax vegetation component and may provide as much of the primary production as the perennials. The Biome research in this area was concluded in 1975. No 1976 projects are proposed.

The third major area of plant process studies has been the investigation of environmental constraints, both physical and biotic, on desert vegetation responses. Two such projects are proposed for 1976. Evan Romney and Arthur Wallace (U.C.L.A.) will conclude their study of water and nitrogen constraints

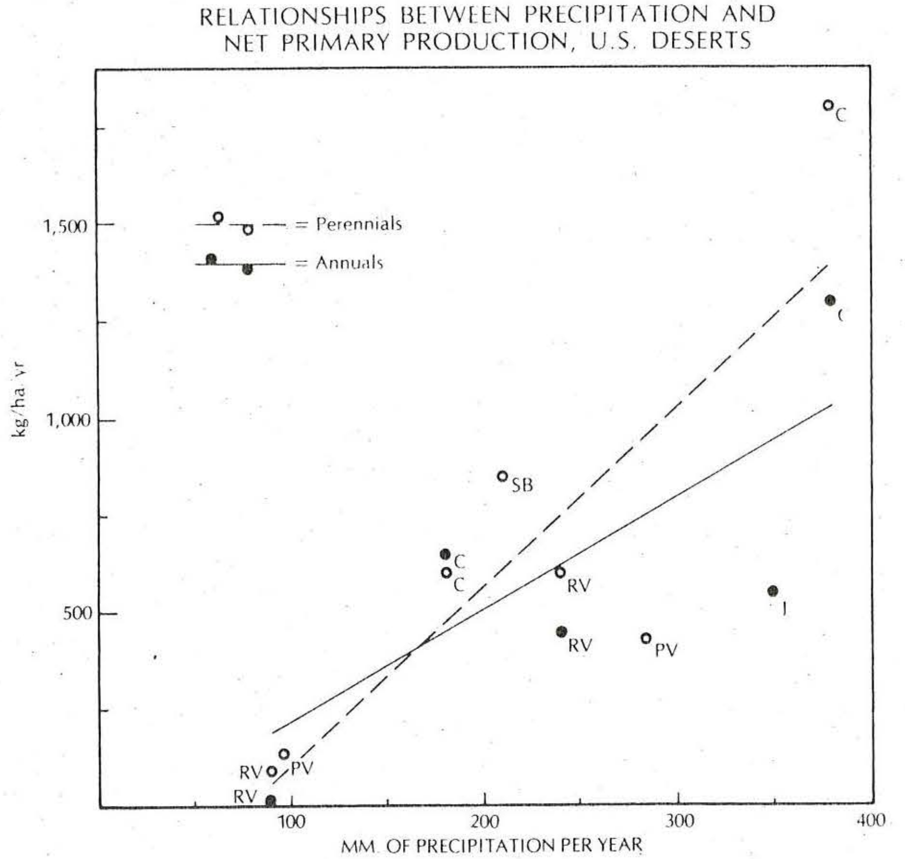


Figure 2

Relationships between primary production and annual precipitation in perennial and annual vegetation on Desert Biome validation sites: Curlew Valley (CV), Jornada (J), Rock Valley (RV), Silver Bell (SB) and Pine Valley (PV). Production values are above-ground dried material.

in the Mohave Desert. James MacMahon and Brien Norton (U.S.U.) will conclude their study of water and herbivory (defoliation) effect on Great Basin shrubs.

In addition, the Cunningham carbon-balance study will include an appraisal of the effects of carbon removal by sucking insects on the carbon-allocation pattern of creosotebush (*Larrea tridentata*).

Vertebrates

Desert vertebrates have been the subject of numerous pre-Biome studies and are among the better researched components of desert ecosystems, particularly in terms of their demography and feeding patterns. The Biome supported only a few such studies in its early years on problems or species important on the validation sites, and in the latter 2 years has turned its support largely to the effects of herbivorous mammals on vegetation. Five projects, wholly or partially on vertebrate problems, are proposed for conclusion in 1976. Four of these are continuing projects, one is a new project designed to fill in one important information gap.

David Balph (U.S.U.) will conclude his study of rodent feeding patterns in Curlew Valley in order to fill in certain blanks in this area of knowledge for the Curlew site.

Three continuing projects will examine the subject of granivory by competing species of desert animals. With herbage production low in desert systems, and annuals a conspicuous part of the vegetation, the seed crops of the latter become a significant part of total primary production and an important potential source of food for desert animals. Three groups of desert animals have evolved into this niche: rodents, particularly the heteromyids in North America; harvester ants which are abundant and conspicuous components of deserts throughout the world; and granivorous wintering birds which migrate in large numbers from other regions into desert areas. These groups may compete for the seed resource and may have some influence on annual plant numbers and/or species composition.

In two companion projects by University of Arizona and Northern Arizona Museum investigators, James Brown and James Reichman will continue their granivory studies in the Sonoran Desert. Brown will investigate rodent and ant competition and foraging strategies, while Reichman will study the extent to which the seed resource is utilized, and the effects of seed foraging, utilization, and caching on annual germination. In the one new project, Ronald Pulliam of the University of Arizona will examine the impact of wintering birds on seed resources in the Sonoran Desert during the winter of 1975-76. This study is needed to complete the picture being developed by Brown and Reichman.

Walter Whitford (New Mexico State University) postulates that ants, rodents, and wintering birds use seeds of different sizes (and therefore plant species). They are not presumed to use enough of the total seed resource to depress annual production. But he postulates that the seeds of certain plant species can be depleted by large bird flocks, or high-density ant populations, or large rodent numbers to the extent that the plant species utilized by one or more of these three groups could be reduced, and the plant species composition thereby affected. Whitford is testing this hypothesis with experimental exclosures from which birds, ants, and rodents can be excluded in varying combinations.

Invertebrates

Because of the large number of species, and the diversity of life-history and feeding patterns, the invertebrates have been the most difficult group of organisms to analyze sufficiently to discern their role in the ecosystem in any quantitative sense, or to model their activities. There have been neither enough funds in the program, nor enough invertebrate ecologists in the participating institutions, to measure up to the task.

The decision was made at an early date not to fund projects on predatory and parasitic species. This reduces the magnitude of the task substantially since there is growing evidence that a large proportion of desert insect faunas are carnivorous. Thus, of the 637 recognized species in Curlew Valley, roughly half are predatory or parasitic, many of them hymenopterous forms. Cloudsley-Thompson (1968) had previously observed a high proportion of carnivorous forms among the insect fauna of Sudanese deserts.

Among the remaining herbivorous and detritivorous forms, there are still more species than the available resources permit individual process studies. Among the defoliators, projects have been funded on a few conspicuous species including leaf-cutter ants in the Sonoran Desert, stem girdlers in the Chihuahuan, and sagebrush defoliators in the Great Basin.

The relationships between plants and herbivores are, of course, reciprocal. From the standpoint of the energy dynamics of the system, particularly that of the consumers, it is important to know the amount of material consumed by them. This consumption will be estimated for insects on the sites by the method described above under validation sites. However, plant-consumption has a control effect on the energy (or carbon) budget of the plant. For the defoliators, this effect will be modeled by calculating the amount of foliage consumed and by reducing the photosynthetic input of the vegetation by this amount.

The role of juice-sucking insects is more remote to rationalize. With population estimates of the numbers of these species over time on the sites, their food consumption can be approximated as described above. Hence estimates of the total sap removed can be attempted. But the reciprocal effects on plant function are the poorly understood aspects of these interrelationships. At this point the most promising hypotheses and analytical approaches seemingly are that the effects lie in the removal of carbon from the plant carbon balances. As mentioned above, Cunningham is probing these effects in connection with his project. No sucking insect projects are scheduled for 1976 except Cunningham's.

The only two invertebrate projects planned for conclusion in 1976 are addressed to organisms involved in the litter break-down phases of the nutrient cycles. Termites appear to be important among these, at least on two sites (Table 2). Hence, the productive termite studies of William Nutting (University of Arizona) will be given a small, phasing-out budget.

Table 2. Dead Wood Production and Termite Consumption Rates on Two Desert Biome Sites

Site	Dead wood produced per year	Wood consumed per year	Investigator
Santa Rita* (Sonoran)	450 kg/ha	414 kg/ha	Nutting
Jornada Playa (Chihuahuan)	1,030 kg/ha	528 kg/ha	Whitford
Jornada Bajada (Chihuahuan)	410 kg/ha	336 kg/ha	Whitford

*The first year of effort in the Sonoran Desert was spent on the Santa Rita Experimental Range near Tucson before permanent site selection was made in Avra Valley.

The only major invertebrate project continuing in 1976 will be the soil nematode study at the University of California, Riverside. Up to the present, these studies have concentrated on Rock Valley and have produced results indicating that these organisms may be among the most important consumers in the conveyance of carbon and energy. The 1976 studies are planned for sampling on the other sites to assess their role in these systems.

Microbial/Nutrient Cycling

Because the nitrogen content of desert soils is low, and because there is some evidence that these low levels are a secondary limiting factor on desert plant production, microbial and nutrient-cycling projects in the Biome have been focused on an elucidation of the desert nitrogen cycle. Projects have been active in Utah, Nevada, Arizona and New Mexico.

John Skujins (Utah State University), working in Curlew Valley has developed a theory to explain the low nitrogen levels in soils of that area. On the basis of present evidence, most of the nitrogen fixation is accomplished by soil algae during periods of low soil moisture stress. However, the soil microflora cannot retain this nitrogen because organic matter in desert soils is scant. There is consequently not a sufficient energy source for their development and retention of the fixed nitrogen. As a result the nitrogen is both denitrified and volatilized as ammonia, and lost from the system. Skujins has worked out this pattern in some detail in Curlew Valley. In 1975 he terminated the Curlew Valley studies and made appropriate measurements in the other four sites during the year to determine whether his scheme is a general pattern of U.S. desert soils. These alternate site measurements will be concluded in 1976.

Wallace and Romney (U.C.L.A.) have conducted studies in the Mohave Desert parallel to Skujins'. They will conclude their project, which is a part of their long-term analyses of nitrogen-cycling processes in the Mohave Desert, during 1976.

Abiotic

Abiotic projects in the Desert Biome have emphasized water, particularly soil-water movement patterns and processes, and the role of the vegetation in soil-water changes. A soil-water model has been developed which effectively simulates changes in soil moisture in Curlew Valley soils. The process studies developed in the past 2 years on soil moisture have been devoted entirely to development of parameters and functions for southern desert soils which could then be used in the Curlew Valley model.

One of these projects will remain in 1976. This is a continuation of three 1974 projects on soil water-vegetation interactive processes in Sonoran desert soils which were merged in 1975. It will continue in the vicinity of the Silver Bell site under the direction of Daniel Evans (University of Arizona).

Aquatic

During its history, the Biome has committed limited funds to four aquatic projects: two on desert spring ponds, one on a disappearing stream (Deep Creek in Curlew Valley) and one on the playa on the Jornada site. Of these, the Deep Creek and playa studies have been the most intensive with continuing activity, even if at a low level, into 1975. The playa studies and support funds are subsumed within the Jornada site program, and only the Deep Creek effort is separately budgeted.

Within the Deep Creek program, Wayne Minshall (Idaho State University) has directed the field research as well as serving as aquatic coordinator. The 1976 budget contains a final project on benthic organisms in the creek. In addition, as described above, an effective model of the creek has been developed over the past few years, and effort will be directed toward finalizing this in 1976 under Wagner's direction at Utah State University.

Synthesis

Program Synthesis

The following document, with slight amendment for this proposal, was presented to the Executive Committee at an early August, 1975 meeting. After discussion, it was adopted as the first iteration of a synthesis outline. As it indicates, site personnel will assume major responsibility for the site synthesis. In order to aid these efforts, four post-doctoral positions have been provided for in the synthesis budget. These fellows will be assigned, one to each site, to assist in the effort.

START

PROPOSED SYNTHESIS PLAN

The overall strategy for Program Synthesis is to generalize ecosystem structure and function for each site, then attempt to generalize across sites depending on the individual site results. Or contrariwise, where marked differences exist between sites, to highlight these differences and hypothesize causation where possible.

The data are not uniform within and between the sites, and it will be possible to develop generalizations on some topics on some sites but not on others. And synthesis here is construed to include the integration of all relevant findings not developed under Biome aegis.

Since the cross-site effort will come later, chronologically, and its dimensions are less clearly visible, this outline is addressed largely to site syntheses. It outlines the aspects of data summaries and generalizations we would like to see derived for each site from the data we have. For the most part, the generalizations on the physical-chemical environment, and on ecosystem structure will come from validation data. We would like these done by validation site personnel where they are willing and/or able. In those cases where they are not, the Central Office will assume the responsibility.

The generalizations on function will come partly from the process data, partly from validation data, partly from the modeling effort, and partly from open literature. We would like much of this done by process-study investigators, but we propose that some be done by Central Office personnel:

I. Physical-chemical environment.

We would like the following tabulated and/or calculated for each site by site personnel or someone provided by the Central Office:

A. Radiation.

1. Monthly total incoming for the years of study.

2. Integrated albedo for each site.

B. Atmospheric temperatures at whatever heights they were measured.

1. Daily mean maxima and minima for the years of study.

2. Daily maxima and minima for the warmest and coldest years.

C. Precipitation.

1. Annual totals for the years of study.

2. Monthly and annual means for the years of study.

3. Weekly total precipitation in absolute terms and as a percentage of the annual totals.

4. Number and percentage of days with measurable precipitation.

5. Stochastic model by Thames.

D. Mean daily drying power of the air.

1. Daily maximum and minimum relative humidity.

2. Daily vapor-pressure deficit calculated for times of maximum and minimum related humidity.

E. Heinrich Walter climate graphs.

F. Soil moisture, weekly means at four depths.

1. Soil water potential (- bars) for points under the canopy and in plant interspaces.

G. Soil physics.

1. Hydraulic conductivity (Stolzy).
2. Thermal conductivity (cal/cm^2, Porter).
3. Soil temperature, weekly means at four depths, plus mean weekly maxima and minima for the surface probe, for the period of study.
4. Bulk densities (g/volume).

H. Soil chemistry: Standard soil laboratory list.

I. Wind at whatever elevations data were taken.

1. Annual and monthly totals for the period of study.
2. Monthly percent of annual totals and direction.

II. Community Structure.

We would like the following calculated for each site by site personnel or someone provided by the Central Office:

A. Diversity, for each year and 6-year totals, and in some cases (e.g. insects) by seasons.

1. Species density for the major habitat types for:
    a. Small mammals (herbivores).
    b. Birds, nesting and wintering.
    c. Lizards.
    d. Insects.
    e. Plants.
2. Alpha diversity for the major habitat types by the Simpson index for:
    a. Small herbivorous mammals.
    b. Birds, nesting and wintering.
    c. Lizards.

d. Insects.

e. Plants.

3. Species-abundance curves for:

a. Small herbivorous mammals.

b. Birds, nesting and wintering.

c. Lizards.

d. Insects.

e. Plants.

4. Number and proportions of plant species in each major habitat type by Raunkiaeir life forms.

B. Spacial configuration.

1. Horizontal vegetation pattern.

a. Vegetation interspecific and intraspecific dispersion patterns by nearest-neighbor measurement and Hopkins, Eberhardt, and Park & Evans tests.

b. Percentage cover.

2. Vertical distribution of vegetation (g/m^2) by species and total at each measurement period:

a. By synusium above ground.

b. At five levels below ground (0-3 cm, 3-10 cm, 10-20 cm, 20-40 cm, and below 40 cm).

C. State variables in biomass, energy, carbon, and nitrogen equivalents (g/m^2) by functional role at each measurement period.

1. Vegetation, by species and total (including annuals).

a. Leaves.

b. Young stems.

c. Old stems.

d. Roots.

e. Flowers and fruit.

f. Standing dead.

2. Litter.

a. Woody.

b. > 2 mm.

c. < 2 mm.

d. Total.

3. Herbivorous small mammals.

4. Granivorous small mammals.

5. Insectivorous birds.

6. Granivorous birds.

7. Lizards.

8. Arthropods.

a. Plant chewing.

b. Plant sucking.

c. Pollen and nectar feeders.

d. Granivores.

e. Fungal and bacterial feeders.

f. Detritivores.

g. Predatory and parasitic.

D. Photosynthetic parameters by species and total at each sampling time.

1. Leaf-area ratio.

2. Green stem-area ratio.

3. Chlorophyll per unit area in leaves.

4. Chlorophyll per unit area in stems.

III. Ecosystem function.

A. Energy/carbon flow.

1. Vegetation carbon balance. This can probably be done with something approaching completeness only for Curlew Valley (Martyn Caldwell) and Rock Valley (Art Wallace). Some portion of the total balance will be possible for Silver Bell (Stan Szarek) and Jornada (Gary Cunningham). It will be done in concert with modeling. In addition Stan Szarek will represent the Biome on an interbiome committee engaging in synthesis on water-use efficiency.

B. Energy-flow budgets for the sites.

We would like these done by site personnel or by persons supplied by the Central Office:

1. Primary production ($g/m^2/year$) by species and total, broken down according to plant parts (same as above for biomass) for each year of study.
2. Bioenergetics, at least consumption and productivity, for major functional groups or guilds of primary consumers (e.g. granivorous mammals, herbivorous insects, etc.) for each year of study.
3. Bioenergetics, at least consumption and productivity, for detritivores for each year of study.
4. Secondary bioenergetics, at least consumption and productivity for arthropods and whatever vertebrates are possible (e.g. lizards, nesting birds) for each year of study.

Items, 2, 3 and 4 will be coarsely approximated and done in concert with the modeling. Process studies will provide some fairly precise estimates on some species and areas (termites on Jornada and Silver Bell; nematodes on Rock Valley; granivores on Jornada, Silver Bell, and Rock Valley; jackrabbits, sagebrush defoliators, and coyotes in Curlew Valley; Uta in Rock Valley; etc.). These estimates will be worked out by (a) site personnel, (b) process-study investigators, (c) modelers, and (d) Central Office personnel, depending on the inclinations of (a) and (b) but with definite input from (c) and (d) in order to assist the modeling effort. A small budget has been included to support Diana Freckman in synthesis of her nematode work.

C. Some efficiency calculations.

Several efficiency or functional-ratio calculations are desirable for each of the sites and are asked of site personnel or Central Office assistance:

1. Vegetation biomass turnover time (maximum standing crop/production calculated for each year of study and averaged) for the following if possible: aboveground, belowground, above and below, above and below and litter.
2. Primary production efficiency (net production/incoming solar radiation calculated for each year of study and averaged) for both above and belowground portions of vegetation.
3. Nitrogen turnover times in vegetation (N_2 standing crop/N_2 fixed in production for each year of study and averaged) for the following if possible: aboveground, belowground, above and below, above and below and litter.
4. Consumption percentages. These are difficult, may be possible for only a few consumer species, and will be crude or order-of-magnitude at best. But we should at least address the questions and see what is possible with our data:

a. Proportion of primary production consumed by all herbivores, by years and averaged.

b. Proportion of annual seed production consumed by granivores, by years and averaged.

c. Proportion of annual litter production consumed by detritivores, by years and averaged.

d. Proportion of herbivores (standing crop or production) consumed by carnivores.

IV. Cross-site Syntheses.

As mentioned above, cross-site or whole-biome syntheses have been planned in less detail than the intra-site efforts (with some exceptions) primarily because we believe the latter must precede the former both conceptually and chronologically. In general principle, the goal of cross-site synthesis will be to develop generalizations about structure and function of North American deserts along the same lines as those outlined above for the sites. We seek general principles of North American desert ecosystem structure and function, particularly as exemplified by common patterns across the five Biome sites. Where differences appear between the different deserts (e.g. north vs. south, Mohave vs. Chihuahuan, etc.), these differences need to be rationalized in terms of environmental and/or evolutionary differences.

We look on the coordination and execution of this effort as the primary responsibility of the Central Office. But much of it has been, and will be, delegated to personnel around the Biome who are interested in participating. The following assignments have been made, or have been agreed to and are scheduled for initiation.

A. The desert nitrogen cycle.

The first, whole-Biome synthesis effort has been underway for 2 years and is near completion. Coordinated by John Skujins, Gene Staffeldt, and Neil West, this effort has pulled together the results of process and validation studies, work outside the Biome, and relevant literature to develop an integrated picture of the desert nitrogen cycle. Chapters have been written on virtually all aspects of the cycle by specialists in and out of the Biome, have been submitted to external review, and together will produce a Biome synthesis volume which has been OK'd for publication by the I.B.P. publication committee. It will be one of the first 3 or 4 I.B.P. synthesis volumes published. An outline of the volume is included as Appendix A.

B. The desert water cycle.

Two years ago at the informational meeting at Tempe, the abiotic people agreed to integrate what is known about desert plant-soil-water processes, and produce a volume on the subject. Three coordinators and editors agreed to assume the responsibility: Dan Evans, John Hanks, and John Thames. Authors have not yet been selected or writing assignments made. But the editors still view this as a worthwhile undertaking, and more definite plans will be made in the next few months.

C. Energy/Carbon flow.

No specific cross-Biome plans or assignments have been made in this area as yet except for granivory and plant water-use efficiency. James Brown and James Reichman have been asked to take on this topic and address such general questions as (1) the magnitude of seed production in deserts; (2) the degree to which this resource is utilized by granivores; (3) the extent to which that utilization influences vegetation structure and function; and (4) the degree to which that resource, and the competition for it, may be limiting to granivore populations. Two, small synthesis budgets have been included to support their efforts. Their outline is included as Appendix B.

An interbiome synthesis effort on plant water-use efficiency is proceeding under the direction of Warren Webb at Oregon State University. Stan Szarek, now at Arizona State University, has been asked to represent the Desert Biome in this venture.

D. Long-term plant community change.

Differences of opinion exist among desert investigators as to whether competitive pressures and competition-related successional patterns exist in desert vegetation. Resolution of this question is crucial to the development of any predictive theory of desert community dynamics which will allow prediction of the vegetation changes and recovery following natural and man-induced perturbation (e.g. grazing, physical disturbance, etc.).

The Biome field research has not addressed these questions to any substantial degree. Hence, the major sources of empirical data are in the literature and in the files of federal agencies which have made vegetation measurements over long periods of time (40-75 years) in experimental grazing areas. Ben Norton has been working on these sources and will continue to do so toward a synthesis effort on the subject, his budget for the effort included under the "Resource Management" title.

E. Phenology.

From his vantage point as a member of the interbiome phenology committee, Jim MacMahon has explored, and will continue to explore, certain aspects of desert phenology. In particular he is interested in seasonal changes in abundance of certain functional groups or components, and the impacts of those changes on the other parts of the system. And some consideration may be given to the extent to which desert phenological events are released from seasonal constraints and freed to respond to precipitation events, and the extent to which these responses are still constrained by seasonal bounds. MacMahon is also chairing an interprogram committee on functional groups.

V. Subsystem synthesis.

Some of the sites and process studies have addressed problems of unique interest which themselves merit intensified effort toward synthesis. These include such cases as the Jornada playa and Jim Reichman's granivory work at Silver Bell. Investigators associated with these cases are being encouraged to work up the results of the studies, and a number of them are scheduled for publication in the Biome monograph series. The first monograph, now in press, is a detailed exposition of the bioenergetics of *Utah stansburiana* by Frederick Turner.

International Synthesis

At the international level, a substantial number of Biome participants are contributing to an international synthesis series to be published by Cambridge Press. Three Biome workers -- David W. Goodall, Frederic H. Wagner, and William McGinnies -- are among the editors and writers. The series incorporates the efforts of arid-land specialists throughout the world and should develop into two to four volumes.

Six Biome investigators are writing chapters of a joint volume on Egyptian and American deserts, the outcome of a bi-national conference in Cairo in 1974. Samir Ghabbour of the University of Cairo and Frederic Wagner are editors.

The Tunisian research ("Systems Analysis of the Pre-Saharan Ecosystem in Southern Tunisia") is scheduled for completion in 1978. Funded by the Smithsonian Foreign Currency Program, this project has addressed the structure and function of the Pre-Saharan ecosystem with emphasis on pastoral utilization of the land, and including energy flow through the local, Arab population. Investigators in this project have agreed to write a synthesis volume in the final year with Frederic Wagner, project director, as editor.

Non-Modeling Synthesis

This program item was provided in 1972 in order to make graduate-student help and computer funds available for the inductive and heuristic analyses described above in the validation-site section. It provides assistance for synthesis activities of central-program personnel.

Resource Management

The U.S. Forest Service and Agricultural Research Service have maintained a number of research stations in arid and semi-arid regions of the Intermountain West. Excellent research programs have been carried on in the areas for periods ranging from 40 to 60 years. Primarily directed to range management problems, these studies have researched various aspects of primary production along with meteorologic and soils measurements.

The Biome program budgeted under the title "Resource Management" was established to develop collaboration with these agency programs. Provision of modeling expertise, assistance with data processing, and judicious assistance with additional field measurements make possible the elaboration of research results from these agency programs in the ecosystem context promoted by the Biome. The relationship is one of mutual benefit to both the agencies and the Biome.

Synthesis Support Functions

All of these activities entail the costs of an editorial staff which was expanded in 1973, of stipends for volume editors, and of printing charges. Travel and subsistence costs for Biome investigators to visit the Central Office in Logan for stays of varying length to work with modeling, data-processing, and editorial personnel are provided in the budget item listed under this subject.

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APPENDIX A

Outline of US/IBP Desert Biome Synthesis Volume

NITROGEN PROCESSES OF DESERT ECOSYSTEMS

edited by

Neil West and John Skujins

Introduction	West and Skujins
Structural Distribution in Desert Ecosystems	West and Klemmedson
Symbiotic Fixation	Farnsworth, Romney, and Wallace
Free Fixation	Rychert, Porcella, and Skujins
Decomposition	Comanor and Staffeldt
Proteolysis and Deamination	O'Brien
Nitrification	Skujins
Denitrification	Tucker and Westerman
Volatilization (Ammonia)	Klubeck, Eberhardt, and Skujins
Plant Uptake	Wallace, Romney, Kleinkopf, and Soufi
Animal Breakdown	Gist and Sferra
Physical Input (rainfall, dust, foliar leaching)	West
Erosional Transport	Sorenson, Fletcher, and Porcella
Modeling I (Theoretical)	Goodall and Parnas
Modeling II (Operational)	Gist, West, and McKee
Summary and Conclusions (Including future research needs)	West and Skujins

APPENDIX B

Outline of Synthesis Project on the ROLE OF GRANIVORES IN DESERT ECOSYSTEMS

Project Leaders: James H. Brown, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson

O. J. Reichman, Museum of Northern Arizona, Flagstaff

Description of Proposed Work:

We agree to undertake a synthetic summary of the role of granivores in desert ecosystems. This summary is intended to synthesize the results of our own research, work by other investigators in the Desert Biome on plants and granivores, and information in the ecological literature. It is expected that this might result in several published papers; at a minimum there probably would be two: one in the summary volume of the Desert Biome and another in a conspicuous peer reviewed journal such as *Ecology* or *Ecological Monographs*. As presently conceived these papers would cover the following topics:

1. The abundance and distribution of seeds.
2. The foraging strategies and seed consumption of the important taxa of granivores.
3. The roles of climate, habitat and competition in structuring communities of granivores, including a discussion of geographic patterns in granivore communities.
4. The impact of granivores on desert plant communities with particular attention to the abundance, distribution, and dynamics of annuals.

At present we are surveying the extent of completed and ongoing research in the Biome to determine what kinds of data are presently available or can be expected before 1976. Discovery at an early date of critical kinds of information that are missing, may enable the Biome to arrange to acquire at least some data during 1976, the last year of Biome research. It has already become apparent that some good, quantitative information on the abundance and impact of granivorous birds at the Silverbell Site would be invaluable to supplement the data of Reichman, Davidson, and Brown on granivorous rodents and ants. We suggest that H. R. Pulliam of the University of Arizona, who has been working for several years on seed-eating grassland birds with NSF support, might be an excellent person to approach about supplying such data.