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Systems Analysis of the Presaharan Ecosystem of Southern Tunisia

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SYSTEMS ANALYSIS OF THE PRESAHARAN ECOSYSTEM OF SOUTHERN TUNISIA

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INTRODUCTION

INTRODUCTION

by Frederic H. Wagner

Project Setting and Objectives

This report summarizes results from the fifth year of field research in the Tunisian PreSaharan Project. Although an overview of the project setting and objectives were given in Progress Report No. 5 (the 1976 report), a repeat of that description is provided here for the readers' convenience, especially those who have not seen, or do not have access to, previous reports.

The Djeffara is a broad plain paralleling, and adjacent to, the southeastern Mediterranean coast of Tunisia and the northeastern coast of Libya. Mean, annual precipitation, occurring mostly between fall and spring, varies between 25-75 mm at the inland margins of the zone to 120-200 mm along the coast. At points in Tunisia, the zone merges into the Grande Erg Orientale of the Sahara, the vast sand-dune sea.

The topography is a rolling one, with sandy soils accumulating in the depressions and lower areas; and thin, gravelly soils covering the gysophillic crust of the low hills and ridges. The vegetation is a stepic or shrub-desert type with shrubs mostly less than 1 m in height, woody perennial forbs or half-shrubs,some perennial grasses, and a diverse annual flora. A dominant species is the composite shrub _Rhanterium suaveolens_, especially on sandy soils. Parts of the Djeffara are sometimes referred to as the "_Rhanterium_ zone."

Where soil depth and quality, and precipitation permit, as in central and northern Tunisia, land owners of this Mediterranean region prefer to grow olives and cereal grains as the major crops. But in the Djeffara conditions are well below optimum for these crops, and they are grown only on that small fraction of the landscape where soils and topography permit, and in that small fracion of years in which precipitation encourages grain planting. In those areas where soils and topography do not permit cultivation, or where natural vegetation is reclaiming areas previously planted to grain, the natural vegetation produces a fodder crop useful to domestic animals.

Hence the environmental realities of the Djeffara constrain the land-use practices to a pastoral one, supplemented by a marginal agriculture. Sheep are the preferred animals, both for their wool and meat, but goats prove to be more hardy in dry years. Since their meat is acceptable and their hair useful, they provide a measure of drought insurance, and consequently the livestock herds are mixed with both goats and sheep.

Until the last few decades, the pastoral pattern was a nomadic one similar to what has evolved in other arid areas of the world. But the nomadic peoples of Tunisia have largely been sedentarized, as have their land-use pressures on the land. These pressures, accelerating very fast by virtue a 2.5 percent annual rate of population growth, now appear to be threatening the continued productivity of the land.

As the perennial plants are grazed heavily, they lose lateral roots, and the soil begins to blow out from under them. The first sign is exposure of several centimeters of taproot, and this is a portent of plant death. Under heavy, continuous grazing, the highly palatable annual plants may be consumed as fast as they germinate. The effect of this is to prevent their growth to the point where they provide some measure of soil protection against the wind; and to the point where they can flower, set seed, and reproduce their numbers in subsequent years.

Deprived of its vegetative cover, the soil begins to move with the wind. Bare, deflated areas are formed on sites from which the soil is transported, while dunes form in areas of accumulation. There is also some evidence that dune formation is promoted in some areas and in some years by cultivation, particularly that of olive groves.

In the arid interior the process appears irreversible. Areas known to have had vegetative cover, both cultivated or wild, within this century are now bare as the Grande Erg has extended its borders. And as a result, productivity has been lost in the process commonly known as "desertiziation."

Closer to the coast, there is evidence that the process can be reversed. If protected from excessive grazing, a distinct flora forms on the dunes including several species of annuals and the coarse perennial grass Aristida pungens. As the surface is stabilized by these specialized dune plants, other plant species gradually move in and the Rhanterium type is eventually reestablished. At some point in the dunal succession, the vegetation is once again attractive for grazing. And with its resumption, the risk once again grows that the soil mantle will be established and movement resumed.

These same successional changes take place on abandoned cultivated areas. By North American desert standards, the succession--involving a complex of annuals, biennials, and shrubby and half-shrub perennials--appears rapid, with a substantial vegetation apparently developing in a matter of 3 to 5 years.

What the net trend is in the entire Djeffara is somewhat conjectural. But a number of observers suspect that more land is going out of production than is recovering. And we postulate that at the least the land still in production is producing at less than its potential, all because the land-use pattern is inimical to an equilibrium situation and to permitting the land to produce at its potential.

Alternate land-use schemes are possible. A given tract of land can be cultivated to different crops, or grazed. And the land can be grazed under different pressures, at different seasons, under different rotations, and with different combinations of animals.

The ecological and land-use challenge is to devise a land-use scheme which would stablize the economic gain for the populace at least on a sustained-yield basis, and hopefully on a gradually increasing basis. It seems highly probable that the land could produce a greater harvest of forage, crops, and animal products under modified land-use practices while the land could be protected at the same time from further degradation. This project has addressed itself to this challenge, aspiring to develop the ecological and social understanding needed to recommend an improved land-use scheme.

First step in attainment of this overall goal was the selection of a research site in southeastern Tunisia within the Djeffara. A rectangular area of about 150 km^2 surrounding the village of Chaabania was selected as an extensive study area in which total acreages of natural vegetation and crops would be determined along with the human population and numbers of domestic animals.

Intensive research sites were acquired in the middle of this rectangle. The first site acquired under lease in 1972 was the Dar ez Zaoui site covering 50 ha of land. In 1974, the 35 ha Henchir es Siane area was added. In 1975 and 1976, additional tracts were added to the point where the intensive sites now total approximately 139 ha.

The intensive sites are used for intensive measurement of ecosystem pattern and process, including destructive sampling. They are used for experiments with different grazing treatments, soil microbiolgoical investigation, wild-animal sampling and experiments, and studies of livestock bioenergetics. Continuous meteorological measurements are made.

The seond step was to set forth objectives for the research. The four general objectives are:

(1) To study primary production and energy flow within the biota, including domestic animals. This initial emphasis on energy was adopted with the realization that all products useful to man could ultimately be converted to economic units.

(2) To study the constraints on primary production and energy flow including:

(a) Meteorologic constraints.

(b) Soil chemical and microbiological constraints.

(c) Impact of different grazing patterns on the vegetation structure and function.

(d) Constraints on crop production including soil instability, as well as (a) and (b).

(e) Use of energy by components of the biota other than livestock and man.

(f) Bioenergetic and demographic constraints on the production of livestock products.

(3) To study the social organization of the local culture including:

(a) Land-ownership and use patterns.

(b) Economic characteristics of the locale including the extent to which the local people gain their subsistence locally from the land, and the extent to which they obtain subsistence by exchange from outside the system.

(c) Family structure and other aspects of social organization.

A major reason for this objective is to develop an understanding of the ways in which the life style and economy are structured around the means for gaining a livelihood so that the impact of any land-use recommendation on the modus vivendi can be judged.

(4) To develop stimulation models of the system, including the social aspects, with which one could simulate the effects of different land-use patterns, and optimization models with which one could determine the optimal land-use patterns.

The research to date, proceeding year by year with more specific objectives, has been designed to meet these objectives:

(1) Vegetation standing crop and annual production have been measured annually, by plant species, in areas protected from grazing, and in areas subjected to grazing by different classes of livestock. These have been related to continuously measured meteorologic variables. Some measures have been taken of small grain and olive yields.

(2) Herbivore consumption and production have been measured, with varying intensity in all classes of consumers:

(a) Invertebrate standing crop, both above and below ground, has been measured several times each year, along with studies of respirometry.

(b) Some rodent standing-crop measurements have been taken.

(c) Observations have been made on consumption by sheep and goats including grazing natural vegetation and supplemental feeding of wild hay, olive boughs, straw and small grain.

(d) Livestock assimilation efficiencies, and production in terms of growth, birth of young, and production of fiber and milk, have all been measured.

(e) Measures have been taken of the amount of natural vegetation harvested by local people for hay, for constructing small structures such as livestock shelters, and for fuel.

(f) Human diets in the area have been studied, and a number of human subjects have submitted to repirometric studies during various daily activities.

(3) Some limited attention has been given to secondary consumption, primarily of lizards and birds, to standing crop and to consumption of animal products by the local people.

(4) Soil chemistry in terms of several ions and organic matter, along with chemical indices of microbial activity, have been measured twice yearly, once in the dry season (summer) and once in the wet season at the beginning of the growing season (January).

(5) Data on family structure, land ownership, and human activity patterns, particularly land-use activities, have been obtained through personal interview.

(6) The first steps toward developing models were taken by constructing flow charts in terms of components, processes, and constraints which constitute conceptual models of the system. Two such schemes have been developed: once which subdivides the natural biota in some detail and treats the human component in rather general categories, and one which treats the total on a rather general plane, but outlines the human in considerable detail.

First steps have been taken in developing the mathematical expressions and writing computer code.

Prologue to Report 6

At this stage of the research, the different components of the ecosystem have been measured during 2 years of subnormal precipitation, 1 approximately normal year, and 2 years with well above-normal rainfall. With observations over this range of variation in the major environmental constraint, the ranges of variation in the system components are becoming evident. And as we are able to visualize the component parts in general perspective, they can increasingly be fit together to provide an emerging view of the system as a whole.

In this report, we are following the procedures of previous years in reporting the activities of the past research year (1976-77). But in a number of cases--e.g. the vegetation and soil microbiology chapters--we also review results from all years of research. And in the final section of the report, we take the first steps toward integrating the parts into an overview of the entire system.

These are, we emphasize, only first steps toward synthesis. Much remains to be done before the accumulated data are fully analyzed and interpreted.

Climatic data need general analysis. More thorough analysis is needed of the vegetation data. The great mass of invertebrate data needs considerable work. The available data on wild vertebrates--rodents, birds, reptiles--have received only very preliminary analyses. The more advanced syntheses--livestock bioenergetics and human studies--are still somewhat preliminary and need further elaboration. Modeling work has proceeded on two fronts: initial work on modeling the whole system and a desertization model, but neither is completed.

These synthetic efforts are proceeding during the current contract year (1977-78) and will have heavy emphasis in 1978-79. In order to facilitate synthesis, field effort was reduced in 1977 from the high level sustained during 1974 through 1976 and will be reduced further during 1978 and 1979. Both 1978 and 1979 will be important years for final snythesis and publication.

Because of this phasing of the research, this will be the last major progress report under the current project supported by the Smithsonian Foreign Currency Program. A small one will probably be submitted in 1978, while a major volume on the entire project is planned for publication in 1979 or 1980. It will be published both in French and English by a Tunisian publisher.

As this pase of the project under the Smithsonian F.C.P. support reaches its goals, a follow-on phase should be initiated. That phase, preferably associated with the UNESCO Man and Biosphere Project 3 (Grazing Lands) should have two major objectives. The first should be to seek the development of land-use programs in Tunisia which apply the findings of the present project and endeavor to inform the local people of the advantages of these new programs. The second should be to experiment further with alternate grazing schemes and cultivation practices. There are many different grazing patterns which might improve range conditions and enhance livestock production, and much remains to be learned about vegetation and livestock response to those patterns. And it seems highly likely that grain yields could be markedly improved through fertilization, and modified cultivation and harvest techniques. Hence there is still a great deal to be learned about, and extensive progress to be made in, improving the condition of the PreSaharan ecosystem and the welfare of the people.

PART II

STATE-OF-THE-SYSTEM MEASUREMENTS

CHAPTER 1

METEOROLOGIC AND SOIL MOISTURE MEASUREMENTS

by Georges Novikoff

Factors of the physical environment were again measured throughout the 1976-77 project year to provide inputs for modeling the ecosystem. Measurements were made on both the Dar ez Zaoui and Henchir es Siane research sites.

Meterologic Measurements

Precipitation.-- For the period September 1, 1976 through August 30, 1977, precipitation at the Dar ez Zaoui weather station totaled 68.6 mm (see Table 1.1). Rains started on the 5th of October and on the whole it was a rather dry year. Mean annual precipitation in this area is believed to be about 90-100 mm, hence the 1976-77 precipitation was about 70 to 80 percent of normal.

Relative humidity.-- Monthly relative humidities were recorded and are summarized in Table 1.2. Seasonal average maxima were as follows: December-February, 90.7%; March-May, 89.9%; June-August, 95.3%. Seasonal average minima were: December-February, 35.5%; March-May, 29.9%; June-August, 31.4%.

Temperature.-- Temperatures were also recorded, as in previous years, and are summarized in Table 1.2. Seasonal temperatures are included in Table 1.3.

Table 1.3

Seasonal Average Maximum, Minimum and Mean Temperatures, 1976-77

	Av. Temp. by Season in °C		
	Dec.-Feb.	Mar.-May	June-Aug.
Maximum	11.7	18.4	15.8
Minimum	6.7	13.6	19.7
Average	20.0	27.2	34.4

Evaporation and wind velocity.-- Monthly evaporation and wind velocity are summarized in Table 1.2.

Soil Moisture Measurements

Soil moisture was measured by the gravimetric method (as before) at four depths: 0-10 cm, 10-20 cm, 20-40 cm, 40-60 cm. Results are presented in Table 1.4 and Figure 1.1 where soil moisture by depth and correlated precipitation events are shown.

Table 1.3

Soil Moisture Percentages by Depth at Dar ez Zaoui

Date	% Water by Weight of Soil Samples				
	0-10 cm	10-20 cm	20-40 cm	40-60 cm	Average
6 Nov. 1976	1.9	2.9	3.6	5.3	3.4
6 Feb. 1977	1.5	2.9	3.5	3.7	2.9
18 Feb. 1977	5.2	6.0	4.5	3.6	4.8
4 Mar. 1977	1.3	3.6	3.7	3.6	3.1
17 May 1977	0.7	1.2	2.2	2.6	1.7
Averages	2.1	3.3	3.5	3.8	3.2

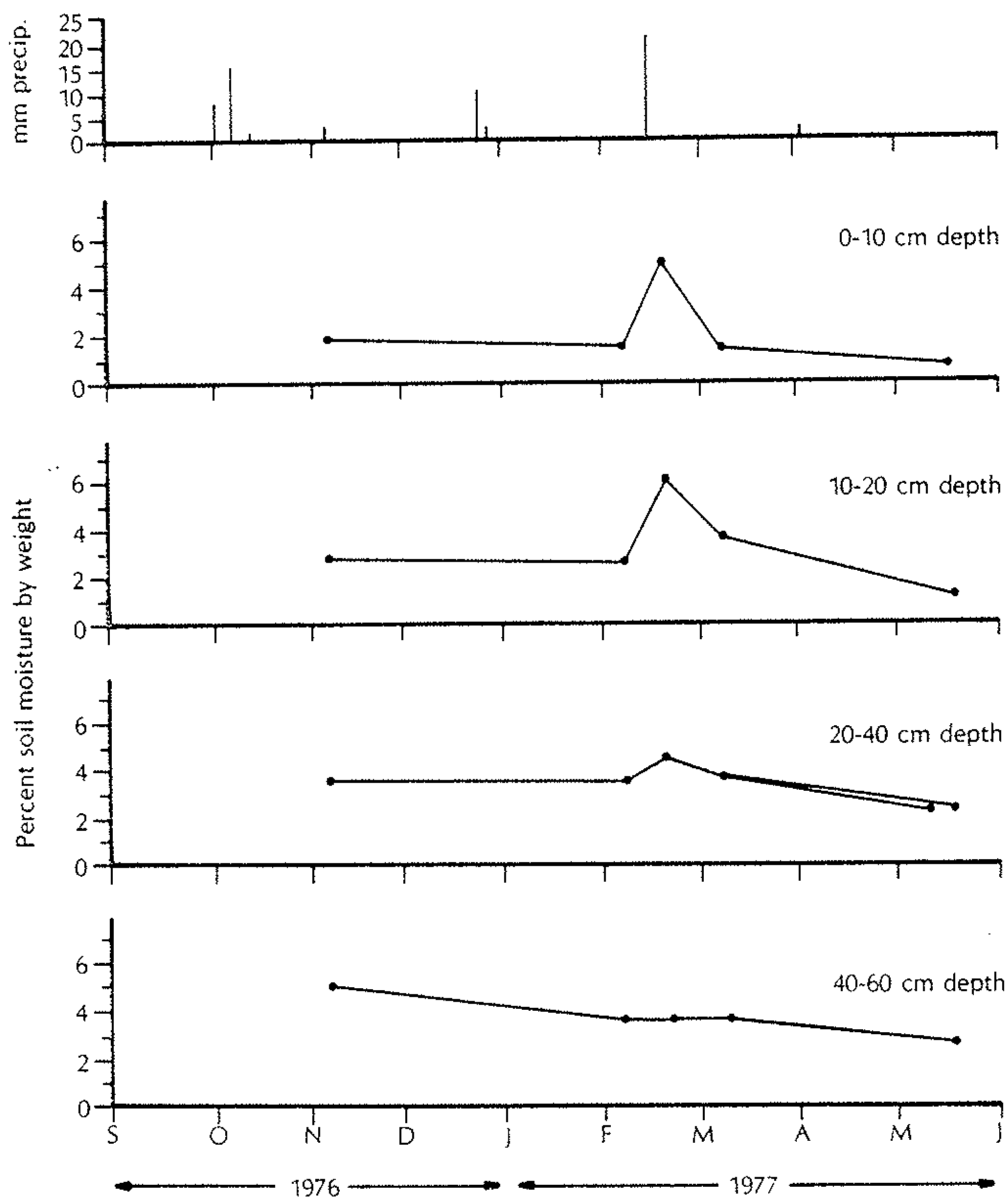


Figure 1.1. Precipitation events and soil-moisture measurements taken at four depths at Dar ez Zaoui between September 1, 1976 and May 30, 1977.

CHAPTER 2

VEGETATION MEASUREMENTS

by George Norvikoff

Objectives

As outlined in the 1976 Progress Report, there are now three major objectives of the vegetation measurments:

(1) Vegetation standing crop and production are measured annually for simulation purposes. Production is measured each year and related to its associated environmental variables, particularly precipitation. The functional relationships which emerge provide the basis for predicting vegetational function over time. Annual measurements of standing crop provide the record of how the system actually changes over time, and it is this change which the models are designed to simulate.

(2) Standing-crop measurements provide information on the vegetation available to herbivores, particularly livestock. Simultaneous studies of food selection provide a basis for calculating food preferences. Measurements of food consumption by herbivores, along with standing-crop measurements, provide a basis for calculating energy flow and the impact of herbivores on vegetation in terms of vegetation utilization.

(3) With the development of the grazing experiments, periodic vegetation measurements record the changes, if any, which the different grazing treatments produce. In the case of areas protected from grazing, the measurements record the successional recovery from the severely overgrazed condition of the land at the time we began the study, and the patterns of vegetation recovery on active dunes and deflated areas. Measurements outside of the research sites in effect constitute controls on the experiments, since they reflect the character of the vegetation under prevailing land use, and of the vegetation on the research sites prior to development of the grazing experiments.

Methods

Experimental design of grazing studies.-- The grazing experiments were begun in 1973-74 on the Dar ez Zaoui site by dividing it into grazed and ungrazed areas, the grazed area subjected to use by mixed flocks of sheep and goats in late spring after most of the vegetative growth had taken place. In 1974-75, the Henchir es Siane site was added and initially subdivided into three tracts: one with late-spring grazing only by goats, a second with late-spring grazing only by sheep, and a third for winter grazing. By 1975-76, an additional plot (Erg Jerbi, or sometimes called Si Mahmoud) was added and both Dar ez Zaoui and Henchir es Siane were further subdivided. The different pastures, their grazing treatments, and

and the letter designations subsequently used in this report are as follows:

(1) Fall and emergency grazing

A_1: Erg Jerbi (Si Mahmoud), grazed by mixed flocks of sheep and goats.

(2) Grazed only in winter

B_1: Henchir es Siane plots I and IV, grazed by mixed flocks.

B_2: Henchir es Siane plot V, grazed by mixed flocks.

(3) Grazed only in late spring

C_1: Dar ez Zaoui, grazed by mixed flock.

C_2: Henchir es Siane, grazed by goats only.

C_3: Henchir es Siane, grazed by sheep only.

(4) Grazed only in summer

D_1: Dar ez Zaoui plots II_A and II_B, grazed by a mixed flock.

D_2: Dar ez Zaoui plots IV_A and IV_B, grazed by a mixed flock. D_2 has been subdivided into two subplots: D'_2 and D''_2.

(5) Control plots with year-long grazing

In fall 1977 control plots adjacent to the Dar ez Zaoui sites in the owership of Saad Boukhli were located. Additional sites adjacent to Henchir es Siane will be located during the 1977-78 winter. These will be designated with the letter E and subscripted numerals to identify the different plots.

(6) Ungrazed plots

F: Ungrazed plots have been maintained at Dar ez Zaoui since the inception of the grazing experiments.

Statistical design.-- As is so often the case with research, the number of sample quadrats used for estimating vegetation standing crop and production has been a function of what could be done with available manpower rather than the number indicated by calculating variances from preliminary samples and prescribing sample sizes on the basis of desired precision at a specified probability level. However, during the current contract year, 1976 data were used to calculate variances and precision levels for different sample sizes.

Two analyses were carried out, the first for determining differences between two values of mean, annual, above-ground production in *Rhanterium suaveolens*. The results are summarized in Table 2.1. Since variability of

Table 2.1

Number of Quadrats Needed to Detect Differences Between Two Mean Annual Production Values of Rhanterium suaveolens at 90% and 95% Confidence Levels

Confidence Level	% Diff.	No. Quadrats Needed to Detect Specified Diff. Between 2 Means				
		Plot C_1 nebka subunit	Plot C_1 normal subunit	Plot C_2	Plot C_3	Plot B_2
90%	5	186	312	107	530	369
	10	47	78	27	133	92
	15	21	35	12	59	41
	20	12	20	7	33	23
	25	7	13	4	21	15
	30	5	9	3	15	10
95%	5	264	444	152	753	524
	10	66	111	38	188	131
	15	29	49	17	84	58
	20	17	28	10	47	33
	25	11	18	6	30	21
	30	7	12	4	21	15

the vegetation differs between different topographic types (nebka vs. normal ground-surface configuration), between Dar ez Zaoui and Henchir es Siane, and between different grazing treatments, quadrat numbers were calculated for these different types.

Review of sample sizes taken in previous years shows that they enabled disclosure of a 20% difference between two means at the 90% confidence level. Sampling intensity during 1977 was increased in order to detect a 15% difference between means.

The second analysis explored the variability in estimated mean, annual production in annuals. Only one topographic-grazing treatment in Dar ez Zaoui was examined, again on the basis of 1976 vegetation sampling. The results are shown in Table 2.2.

Table 2.2

Number of Quadrats Needed to Detect Differences Between Two Mean, Annual Production Values of Annuals at 90%, 95% and 98% Confidence Levels

	No. Quadrats Needed For Specified Diff. Between Means			
Confidence Level	5% Diff.	10% Diff.	20% Diff.	30% Diff.
90	156	39	10	4
95	221	55	14	6
98	311	78	19	9

The 1975-76 rainfall total was far above normal. It is conceivable that the level of variability may differ between wet and dry years, nearly all sites being suitable for annual growth in a wet year but only the more favorable sites being suitable in a dry year. Consequently, annual dispersion may be more uniform in a wet year and the variances smaller. This possibility will be explored in the coming year.

Estimation of underground biomass.-- The first efforts to estimate root biomass were begun in 1976 with emphasis on Rhanterium. The method used to extract roots from the soil -- basically by washing the soil away from the base of the plant with water --was described in the 1976 Progress Report. Since this is a tedious procedure, the ultimate goal has been to regress root mass on above-ground mass, and once the relationship is ascertained, root mass can then be estimated from measurement of the above-ground portion. In that way root biomass can be estimated for all areas of the research sites, and compared between experimental treatments in the same manner as with the above-ground vegetation.

In 1977, these studies were expanded to include the following species:

(1) Annuals and annual-like or biennial species:

Plantago albicans
Zollikoferia resedifolia spp eu-resedifolia

(2) Small-sized perennials:

Argyrolobium uniflorum
Nolletia chrysocomoides
Linaria fruticosa spp. aegyptiaca
Helianthemum lipii var. sessiliflorum

(3) Rhanterium suaueolens

The same sprinkling method was used as in 1976 with one additional technical innovation. The roots of many of the plants penetrate the calcareous hard pan which lies at varying depths below the soil surface ranging from a few cm to 1 to 2 m (cf. May 1973 Progress Report). In cases of root penetration, the hard pan was broken manually in order to extract the roots.

Results

Underground biomass.--

Root morphology of the local plants: Root morphology of the plants varies between species and with plant age. The two annual or biennial species have a central tap root which makes up a major portion of the total root mass, and lateral roots of lesser mass and less lateral extension than depth to which the tap roots penetrate. Of 45 Plantago individuals examined, mean root depth was 46.2 cm , 56% of which penetrated the hardpan. Of 42 Zollikoferia plants examined, mean root depth was again 46.2 cm with 24% of the plants penetrating the hardpan.

Root structures of the small-sized perennials were similar to those of the annuals or biennials in having systems depending primarily on central taproots. Two of the species (Argyrolobium and Linaria) had no lateral roots (samples of ten plants each), one of 11 Argyrolobium plants had minor lateral development, and three of ten Helianthemum plants bore lateral roots. Charateristics of root structure in these species are summarized in Table 2.3.

Root structure of Rhanterium differed from the other species in having substantial development of lateral roots around the taproot, although this occurred largely in plants of medium and older age. Root systems of these plants were more extensive than those of other species, and on average the medium- and older-aged plants were able to extend their roots to greater depths by penetrating the hardpan and protruding through it. Many of the roots failed to penetrate, however, and upon reaching the hardpan became distorted and grew laterally. The details of these measurements are summarized in Table 2.4.

Table 2.3

Root Characteristics of Four Small Perennial Species at the Dar ez Zaoui Site

Species	No. Plants	Av. Root Depth (cm)	% With Lateral Roots	% Extending Thru Hardpan
Argyrolobium uniflorum	10	47.1	0	0
Nolletia chrysocomoides	11	58.4	1	0
Linaria fruticosa spp. *aegyptiaca*	10	48.7	0	0
Helianthenium lipii var. *sessiliflorum*	10	36.8	30	20

Table 2.4

Root Characteristics of *Rhanterium suareolens* Shrubs at the Dar ez Zaoui Site

Shrub Type	No.	Characteristics of Root System				
		Av. Length Longest Root (cm)[2]	Av. Max. Depth[3] (cm)	% With Lateral Roots	Av. Lateral Extension (cm)	% Extending Thru Hardpan
Seedling	3	32	32	0	0	0
Young	3	49	49	0	0	0
Medium	3	72	61	100	62	100
Older						
Normal[1]	3	178	44	100	118	0
Nebka[1]	3	148	73	100	132	100

[1] Refers to soil surface type.

[2] Length of uncurled extended root.

[3] Maximum depth to which unextended root system penetrated.

Clearly, from these results, the lateral roots of Rhanterium plants which reached sufficient age occupy more soil volume than the vertical roots and presumably play a more significant role in water and nutrient uptake.

Among the species analyzed here, the two annuals or biennials, the small perennials, and the young Rhanterium largely occupy the soil stratum above the hardpan and rely primarily on taproot function. The older Rhanterium occupy this same stratum, but perfuse it with extensive lateral root development. In addition most of the older Rhanterium, and a substantial fraction of the Plantago, Zollikoferia, and Helianthemum penetrate the hardpan and occupy the soil below it.

Correlation between root and above-ground biomass: Weights of dried roots of each plant were regressed on the weights of dried, above-ground portions of the plants (Table 2.5). All of the tests yielded statistical significance and both the regression equations and root/shoot ratios provide the basis for estimating root biomass when above-ground phytomass is known.

Table 2.5

Regressions of Root Dry Weights on Dried Above-ground Phytomass and Shoot/ Root Ratios for Seven Dar ez Zaoui Plant Species

Species	n	Correl. Coef. (r)	Regression Equation	Root/shoot Ratio
Plantago albicans	45	0.57**	$\hat{Y} = 0.29 + 0.11x$	0.31/1
Zollikoferia resedifolia ssp. eu-resedifolia	42	0.95**	$\hat{Y} = 0.25 + 1.17x$	1.25/1
Argyrolobium uniflorum	10	0.62*	$\hat{Y} = 0.67 + 0.04x$	0.23/1
Helianthemum lippii var. sessiliflorum	10	0.94**	$\hat{Y} = 0.31 + 0.17x$	0.20/1
Nolletia chrysocomoides	11	0.67*	$\hat{Y} = 0.66 + 0.22x$	0.36/1
Linaria aegyptiaca ssp. fruticosa	10	0.97**	$\hat{Y} = 0.81 + 0.08x$	0.10/1
Rhanterium suaveolens	15	0.85**	$\hat{Y} = 3.03 + 0.15x$	0.16/1

* Significant at .05 probability level.

** Significant at .01 probability level.

Estimation of root biomass on Dar ez Zaoui area: Root biomass for the seven species discussed above has now been estimated for three of the grazing treatments of the Dar ez Zaoui area: C_1 (spring grazing by mixed flocks), and D_1 and D_2 (summer grazed by mixed flocks). These are summarized for the two annual or biennial species, and for the four small perennials. Since above-ground growth starts anew for these species each year, and above-ground production and biomass at the end of the growing season are the same and measured annually, the root estimations were made with the root/shoot ratios. Estimates were made separately for the "normal" or relatively even soil-surface type, and the nebka (humped or hummocked) soil-surface types (Table 2.6).

Table 2.6

Above-ground and Root Biomass per Hectare for Six Species on Dar ez Zaoui Plots C_1, D_1, D_2

Species	Root/ Shoot Ratio (A)	Kg Dry Matter per Ha: Normal Submit Above-ground (B)	Normal Submit Root (AxB)	Nebka Submit Above-ground (C)	Nebka Submit Root (AxC)
Annuals and Biennials					
Plantago albicans	0.31	34.3	10.3	20.3	6.3
Zollikoferia resedifolia spp. eu-resedifolia	1.25	11.8	14.8	22.7	28.4
Totals		46.1	25.1	43.0	34.7
Small-sized perennials					
Argyrolobium uniflorum	0.23	32.7	7.5	25.5	5.9
Nolletia chrysocomoides	0.36	4.7	1.7	1.7	0.6
Linaria aegyptiaca ssp. fruticosa	0.10	38.6	3.9	4.0	0.4
Helianthemum lipii var. sessiliflorum	0.20	13.1	2.6	19.7	3.9
Totals		89.1	15.7	50.9	10.8

Estimates were also made for Rhanterium. Total biomass on this large shrub is not measured annually while above-ground production is. Although the correlation of root mass is not as strong with above-ground primary production ($r = 0.73$, $n = 15$) as with above-ground biomass ($r = 0.85$, $n = 15$), root biomass was estimated from annual production because it is more generally measured.

Additionally, the root/production ratio appears to decline as plant size increases. Consequently root/production ratios were calculated for seedlings, young plants, and more mature plants; and root biomass was estimated for each of these groups with their own root/production ratios. These are shown in Table 2.7. Once again estimates were made separately for normal and nebka soil types in grazing treatments C_1 and D_1, but they were not partitioned in D_2.

Vegetation production under different grazing treatments.--

Annuals and perennials other than *Rhanterium*: Production of all species except *Rhanterium* during the 1976-77 growing season, subdivided by grazing treatment, is summarized in Table 2.8. In general, these results show roughly twice the production of annuals and biennials, and of small perennials in the Dar ez Zaoui sites (C_1,D_1,D_2) as in the Henchir es Siane sites (C_2,C_3) with the exception of B_2. This site produced more annuals than any other site, and produced small perennials at roughly twice the rate of the other Henchir es Siane sites. However, Henchir es Siane sites C_2 and C_3 had the highest production of small shrubs and perennial grasses (if the two D_1 subunites are averaged together), and well over half of this was *Artemisia campestris*.

One possible explanation for the high production of annuals and small perennials in B_2 is the fact that this site was rested from grazing for 3 years. *Artemisia campestris*, on the other hand, appears to increase under grazing pressure.

Within the annual and bienniel production, *Plantago albicans* and *Zollikoferia resedifolia* ssp. *eu-resedifolia* make up 37 to 40 percent of the total in C_3 and C_2 respectively; and from 49 to 78 percent of the total in the other sites. The higher value was obtained for B_2. Among the small perennials, *Argyrolobium uniflorum* production was lowest on sites C_2 and C_3, considerably higher on the other areas constituting from 17-50 percent of the total. Once again total production of this species, and its percentage of the total, were highest in B_2.

All of the above species -- *Plantago*, *Zollikoferia* and *Argyrolobium*-- are highly palatable to both sheep and goats (see later Chapter by D.C. and K.L. Crocker-Bedford), and their abundance in B_2 may again reflect its 3-year respite from grazing. Their relative scarcity on C_2 and C_3, along with the abundance of *Artemisia campestris*, reflects the relative poverty of the range conditions in these sites.

The significance of *Plantago*, *Zollikoferia* and *Argyrolobium* is increased by the fact that they respond promptly and early to fall rains, and are therefore important in providing winter forage at a time when other species either have not begun to develop or are doing so much more slowly.

Rhanterium suaveolens: Production of *Rhanterium* was measured in each of the grazing treatments by clipping current annual growth at the end of the growing season in 2 x 10 m quadrats. Growth of each shrub

Table 2.7

Above-ground Annual Production and Root Biomass for <u>Rhanterium suaveolens</u> on Dar ez Zaoui Plots C_1,D_1,D_2

Area and Plant Age	n	Mean Kg Produced Per Plant (A)	Mean Kg Roots/ Plant (B)	Ratio ($\frac{B}{A}$)	Kg Dry Matter Produced/Ha by Soil Type: Nebka (C)	Kg Dry Matter Produced/Ha by Soil Type: Normal (C)	Kg Roots/Ha by Soil Type: Nebka ($\frac{B}{A}$xC)	Kg Roots/Ha by Soil Type: Normal ($\frac{B}{A}$xD)
C_1								
Seedling	3	0.4	0.3	0.75	14.6	7.0	11.0	5.3
Young	3	18.3	4.2	0.23	58.3	29.9	13.4	6.9
Mature	9	370.8	111.4	0.30	195.4	161.4	58.6	48.4
Totals					268.3	198.3	83.0	60.6
D_1								
Seedling	3	0.4	0.3	0.75	7.4	5.7	5.6	4.3
Young	3	18.3	4.2	0.23	50.6	26.6	11.6	6.1
Mature	9	370.8	111.4	0.30	177.9	154.5	53.4	46.4
Totals					235.9	186.8	70.6	56.8
D_2								
Seedling	3	0.4	0.3	0.75	3.7		2.8	
Young	3	18.3	4.2	0.23	29.8		6.9	
Mature	9	370.8	111.4	6.30	91.3		27.4	
Totals					124.8		37.1	

Table 2.8

Above-ground Production Under Different Grazing Treatments of Annuals and Small Perennials Other Than Rhanterium in 1976-77

Species	Kg Dry Matter per Ha by Grazing Treatment							
	B_2	C_1 Nebka	C_1 Normal	C_3	C_2	D_1 Nebka	D_1 Normal	D_2
Annuals and Biennials								
Plantago albicans	48.6	31.4	20.7	11.9	12.3	25.3	18.6	32.8
Zollikoferia resedifolia	47.8	20.3	24.7	4.3	1.4	15.8	28.2	13.5
Others	26.5	23.1	16.7	27.9	20.6	30.5	20.2	48.1
Subtotals	122.5	74.8	62.1	44.1	34.4	71.6	66.9	94.4
Small Perennials								
Argyrolobium uniflorum	33.8	25.5	33.0	7.1	6.2	15.4	22.0	17.6
Linaria aegyptiaca	23.8	4.0	18.3	11.6	9.3	13.9	26.4	25.8
Helianthemum lipii	8.3	19.7	13.5	2.9	1.9	5.3	4.0	10.1
Fagonia glutinosa	1.2	0.3	0.1	4.0	2.4	0.7	0	0.8
Pituranthos tortuosus	11.8	0.5	0.8	2.4	0.9	Tr	0.5	0
Astragalus gyzensis	0.2	0	0.1	0.6	Tr	0.7	0.5	0.1
Astractylis candida	1.8	9.3	7.4	0.9	0.7	12.7	14.3	8.1
Nolletia chrysocomoides	0.3	1.8	11.5	0.1	0.1	4.7	2.5	21.9
Echiochilon fruticosum	0.7	1.7	0.2	1.5	0.4	17.5	24.0	3.1
Erodium glaucophyllum	0	0	1.1	0	0	1.5	0	18.6
Teucrium pseudo-chamaepithys	0	0.1	0.1	0	0	0	0.2	0
Subtotals	67.3	62.6	86.1	43.3	24.2	72.5	94.3	105.3
Small Shrubs and Perennial Grasses								
Stipa fontanesii	0.7	12.6	3.7	0.2	Tr	19.1	8.7	2.3
Lygaeum spartum	7.9	0.9	0.3	Tr	1.6	111.2	0.5	0.1
Gymnocarpus decander	0	0.4	0.5	0.4	0.5	0	2.0	0.3
Polygonum equisitiforme	3.8	0	0.5	0	Tr	0	Tr	0
Aristida pungens	0	0.5	5.1	0	0	0	0	0.6
Atractylis serratuloides	0	0	0.1	9.5	0	2.0	2.5	0
Arthrophytum scoparium	0	0	0	1.3	0.2	0	0.2	0
Artemisia herba-alba	0	0	0	0	Tr	0	0	0
Salsola vermiculata (yg.)	0	1.8	1.6	0.4	2.3	0	0	0
S. vermiculata (ad.)	0	42.1	27.6	3.1	8.4	0	0	0
Artemisia campestris (small)	0	0.1	0.5	20.4	4.8	0	0	0
A. campestris (medium)	0	0	0.8	43.5	25.2	0	0	0
A. campestris (large)	0	12.5	34.2	36.2	39.0	0	0	0
Subtotals	12.4	70.9	74.9	114.9	82.0	122.3	12.1	3.3
Retama raetam	0	25.8	106.2	0	0	0.8	0.6	21.3

within the quadrats was clipped, oven dried, and weighed. The results, expressed in terms of kg/ha are summarized in Table 2.9.

Table 2.9

Above-ground Production of Rhanterium suaveolens in 1976-77 Growing Season

Grazing Treatment	No. Quadrats Sampled	Kg Dry Matter/Ha by Shrub Age			
		Seedlings	Young	Adults	Total
B_2	44	14.3	37.3	120.0	171.7
C_1 Normal	34	7.0	29.9	161.4	198.3
C_1 Nebka	20	14.6	58.3	195.4	268.3
C_2	19	14.4	36.8	173.4	224.6
C_3	15	9.5	23.2	90.4	123.2
D_1 Normal	18	5.6	26.6	154.5	186.7
D_1 Nebka	18	7.4	50.6	177.9	235.9
D_2	15	3.7	29.8	91.3	124.8

These results show some differences between treatment which may or may not be cause and effect. Lowest Rhanterium production was measured in treatment C_3, the spring sheep-only pasture. That production was significantly lower, statistically, than the adjacent ecologically similar C_2 pasture used in spring by goats only. That goats are more characteristically browsers than sheep (see 1975 Progress Report by Griego and the forage preference studies by D.C. and K.L. Crocker-Bedford in this report) is not in accord with the low Rhanterium presence in pasture C_3. Vegetation trends in these two types will be followed in the future years to determine whether the amounts of Rhanterium in C_2 and C_3 diverge further (both are at Henchir es Siane).

Aside from this comparison, some additional aspects bear watching. Treatments C_1, D_1 and D_2 are mixed-flock treatments at Dar ez Zaoui, C_1 being spring grazed and the latter two being summer grazed. D.C. Crocker-Bedford has pointed out that the greatest variety and abundance of forage is available in spring and hence the least grazing pressure will be applied to an unpalatable species at this time. C_1 has higher production of Rhanterium than D_1 and D_2. One might speculate that lighter pressure on Rhanterium in C_1 has encouraged its increase. By summer annuals are largely gone and sheep as well as goats turn increasingly to Rhanterium and reduce its abundance in the vegetation.

In this same connection, Rhanterium is probably important in the winter season before new growth of annuals and other perennials has assumed importance. Hence the low amount of Rhanterium in B_2 by comparison with C_2 and C_3 (all treatments are at Henchir es Siane) may be significant.

This is all speculative at present, but the trends will be observed in the years ahead.

Retama raetam: Production is measured in this species through a form of dimensional analysis and has been described in previous reports. In brief, height and diameter of samples of individual plants are measured and their volumes calculated. The new growth from these same plants at the end of the growing season is clipped, dried and weighed; and the new-growth weight for each plant is regressed on its volume. The regression equation is then used to estmate new growth on plants in sample plots for which volume only is determined.

Retama, though a large shrub, is not an abundant plant and to clip the production from each plant in each sample quadrat each year would potentially have a significant impact on the species. It is for this reason that this indirect approach is used.

Small and larger shrubs were regressed separately, the correlation coefficient for the small one being 0.98, and for the large ones 0.88. Actual per hectare production estimates are shown in Table 2.8 The species is virtually absent from the Henchir es Siane pastures, and hence values are only shown for those at Dar ez Zaoui.

Total 1976-77 production: The values for all of the plant groups can be added to estimate the production per hectare for the different grazing treatments (Table 2.9). The major points that can be inferred from these data are that in a year with subnormal moisture, like 1976-77, roughly 40 to 60 percent of the production is contributed by the two larger shrubly species. Consequently, in those grazing and soil-surface types with the larger amounts of Retama and Rhanterium, total production tends to be greater. Except for D_2, the Dar es Zaoui treatments tend to have higher production than the Henchir es Siane areas, evidently for this reason.

Relation of production to precipitation.-- In the 1975 Report, production of annuals, of small perennials, and of Rhanterium was regressed on precipitation for a 3-year period. In the 1976 Report, this was updated for annuals for a fourth year. These regressions cover the 4-years 1973 through 1976 during which precipitation rose each year to a record high in 1975-76 that was about five times normal. In each case, the relationship appeared adequately represented by a straight line with very low variance among the individual points. In the 1976 test, the 4 years of annual production were also well represented by a parabolic equation with very slight curviture, and again a tight fit of points. Addition of

Table 2.9

Total Above-ground Net Primary Production in 1976-77 Within the Grazing Treatments

Species Group	Kg/ha Produced by Grazing and Soil Type							
	B_2	C_1 Nebka	C_1 Normal	C_2	C_3	D_1 Nebka	D_1 Normal	$D_1 + 2$
Annuals and Biennials	122.5	74.8	62.1	34.4	44.1	71.6	66.9	94.0
Small Perennials	67.3	62.6	86.1	24.2	43.3	72.5	94.3	105.3
Perennial Grass & Small Shrubs	12.4	70.9	74.9	82.0	114.9	122.3	12.1	3.3
Retama raetam	0	25.8	106.2	0	0	0.8	0.6	21.3
Rhanterium suaveolens	171.7	268.3	198.3	224.6	123.2	235.9	186.7	124.8
Totals	373.9	502.4	527.6	365.3	325.5	503.1	360.6	348.7

the 1976-77 rainfall and production data to these previous tests now sheds new light on the relationship of primary production to precipitation.

The relationship between annuals and precipitation in Pasture C, remains a closely fit straight line ($r^2 = 0.97$) with the equation $\hat{Y} = -12.4 + 1.84x$. Obviously, virtually all of the between-year variation in production of annuals is associated with variation in the precipitation of the same year. The negative intercept suggests that there may be a lower precipitation threshold below which no annual growth can take place, perhaps at around 7 to 10 mm.

With the addition of the 1976-77 data, the relationship with small perennials deviates somewhat from a tight, straight-line regression (Figure 2.1). The 1976-77 production value is roughtly twice what the previous years' data would predict. The same statements can be made about the relationship between *Rhanterium* production and precipitation (Figure 2.2).

One can only speculate at this stage on the higher-than-expected production of perennials in 1976-77, but several possibilities present themselves. One is the more extensive (and deeper) root systems of the perennials which may have enabled them to utilize vestiges of 1975-76 moisture. The 497 mm falling in that year was roughly 5 times normal. Some of it may still have been present in the deeper soil profiles. In particular, some may have seeped through the hard-pan where it was relatively protected from evaporation, and penetration of the pan by *Rhanterium* roots made the reserve available to this species.

Alternatively, there may have been some moisture storage within the plants themselves.

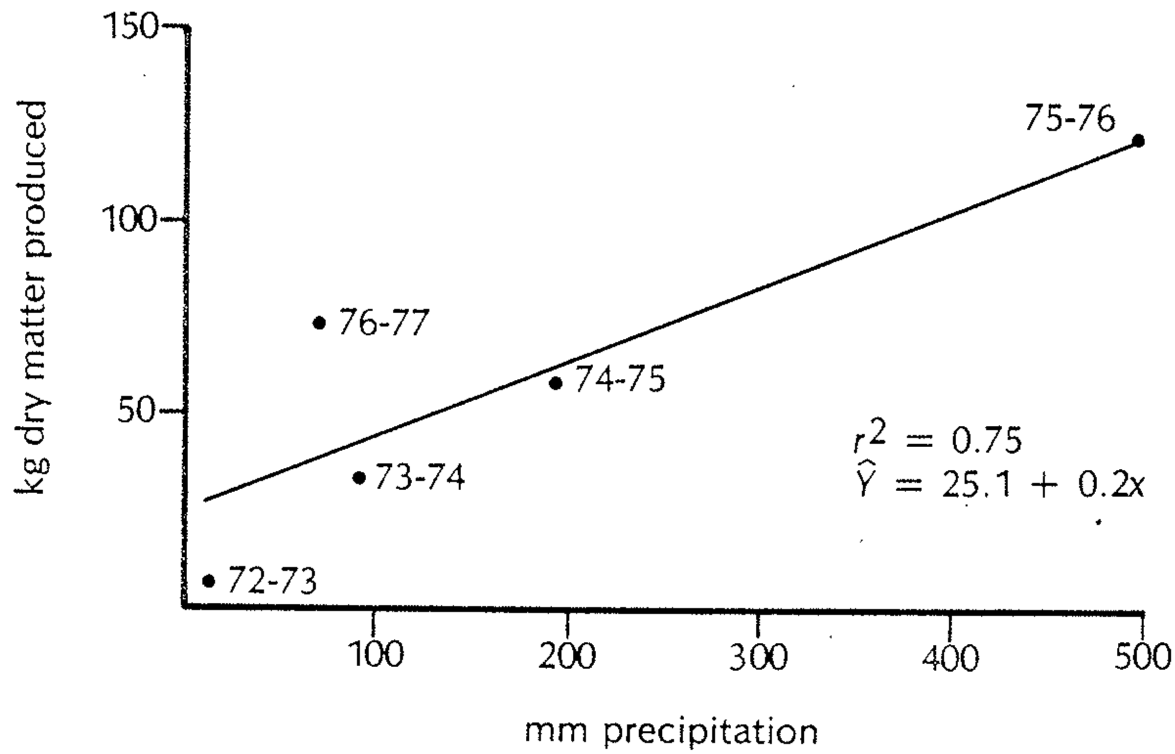


Figure 2.1. Regression of net, above-ground primary production by small-sized perennials on annual (October-September) precipitation.

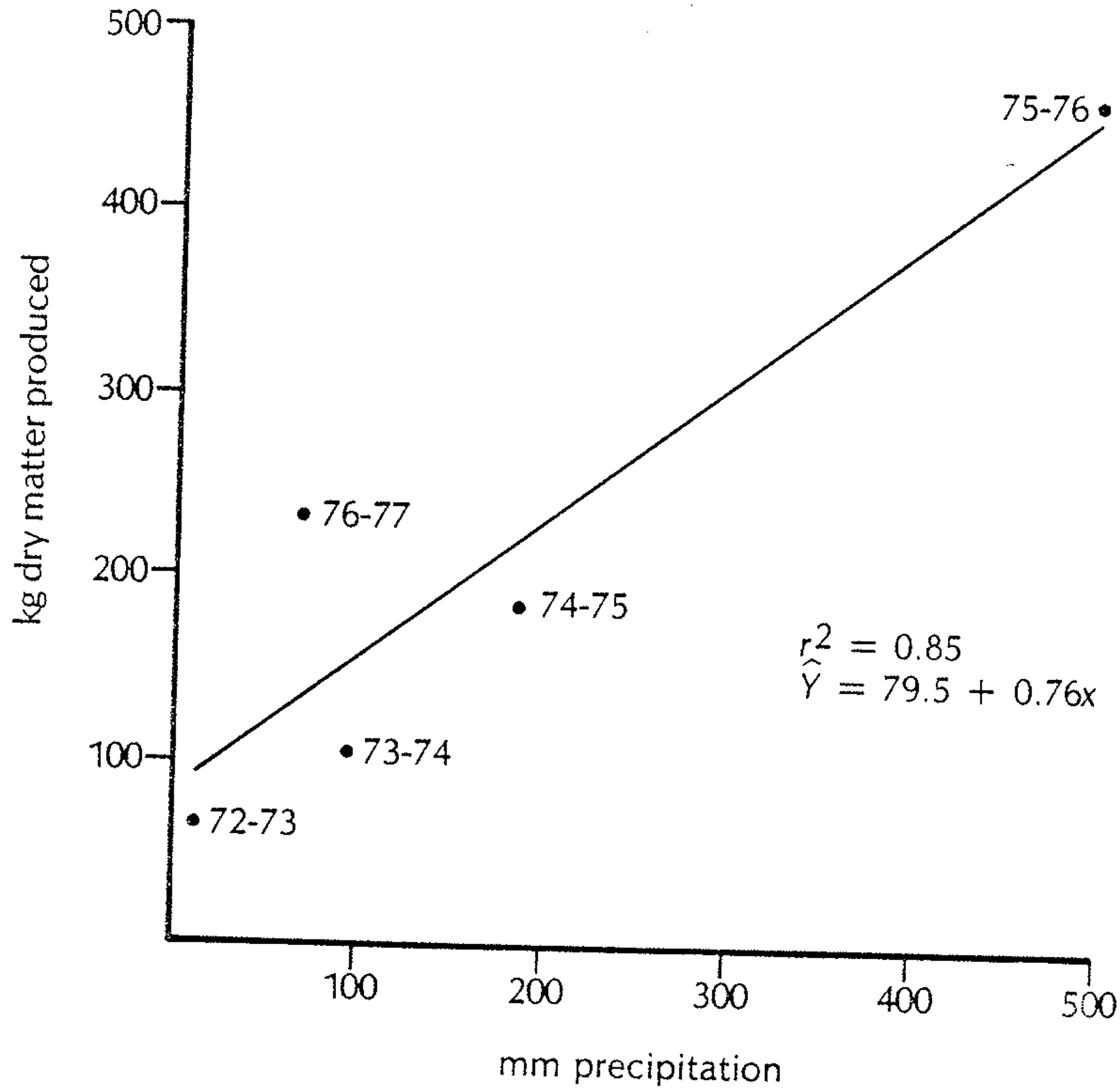


Figure 2.2. Regression of net, above-ground primary production by Rhanterium suaveolens on annual (October-September) precipitation.

CHAPTER 3

INVERTEBRATE POPULATION AND BIOMASS

by R.J. Muir and H. Heatwole

Introduction

From the end of 1976 and during 1977 the field program was reduced to allow the completion of laboratory work and drafting for final publication. Hence this progress report on the animal fauna is accordingly reduced.

In most studies only 2 of the original 6 soil-surface and erosion-type areas are now under study. (See Report Progress No. 5 (1976) for all area designations). These are:

Area 1-3: A combination of three original areas, non-grazed, characterized by generally loose soil which often forms nebkas (sand mounds) around perennial shrubs, and is subject to some wind erosion.

Area 6: Heavily grazed area outside the Research Site, of a similar soil and erosion type to Area 1-3, but subject to almost continuous grazing.

In addition, a portion of Area type 1-3, grazed in spring by project flocks, is now under study in ant, beetle and rodent studies. This has been designated Area 7. Areas 4 and 5 have been discontinued in all studies except the snail study.

Area 4: Dune areas with deep sand.

Area 5: Crusted surface areas subject to strong wind and water erosion.

Cage Samples

Methods.-- Methods applied are identical to those applied since 1973 (see Progress Report No. 2, Heatwole and Davison). Since the 1976 report, cage samples have been taken in autumn 1976, winter 1976-77 and spring 1977. Both Areas 1-3 and 6 were studied.

Results.-- Until cage results can be sorted, using computer techniques, in conjunction with plant biomass data, results here can only be presented in a gross form. However, this presentation still allows a comparison between different sample areas, seasons and years.

Invertebrate density per kilogram standing crop: The number of individual invertegrates per unit dry weight of the perennial shrub provides an estimate of the invertegrate population supported by perennial plants. Above-ground cage results were treated in three ways:

(1) Aleurodid larvae were examined separately, per kilogram of above-ground Rhanterium, as they far exceeded in density all other perennial-associated species combined (Table 3.1).

(2) Rhanterium-associated invertebrates (excluding Aleurodid larvae) were measured per kilogram of above-ground Rhanterium (Table 3.2).

(3) Total perennial-associated invertebrates (excluding Aleurodid larvae) were measured per kilogram of above-ground perennials (Table 3.3).

Table 3.1

Number of Aleurodid Larvae per Kilogram Above-ground Rhanterium Standing Crop Taken in Cage Samples, 1976-77

	No. Aleurodid Larvae/kg Dried Rhanterium by Season		
Area	Autumn 1976	Winter 1976-77	Spring 1977
1-3	56,942	31,285	68,997
6	38,522	74,529	114,514

Results show a far higher production of Aleurodid larvae in the 1976-77 study than in the previous year for the same seasons. The highest number of Aleurodid larvae per kilogram Rhanterium in 1975-76 did not exceed 13,000 for any area in the same seasons. Area 6 showed an increase in Aleurodid larvae from autumn to spring (Table 3.1).

Table 3.2

Numbers of Invertebrates (Excluding Aleurodid Larvae) per Kilogram Above-ground Rhanterium Standing Crop Taken in Cage Sampling, 1976-77

	No. Invertebrates/kg Dried Rhanterium by Season		
Area	Autumn 1976	Winter 1976-77	Spring 1977
1-3	1066	392	366
6	589	353	1071

Rhanterium-associated invertebrate (non Aleurodid) numbers declined from autumn to spring in Area 1-3 but rose sharply in Area 6 between winter and spring. Results were similar to those in the previous year, 1975-76, except in spring where 1977 invertebrate numbers were higher in Area 6 and lower in Area 7 than those in 1976 (Table 3.2).

Total numbers of invertebrates per kilogram of perennial standing crop generally reflected results per kilogram of *Rhanterium* standing crop, indicating that invertebrate numbers associated with non-*Rhanterium* perennials are similar to those associated with *Rhanterium* per unit weight of shrubs (Tables 3.2, 3.3).

Table 3.3

Numbers of Invertebrates (Excluding Aleurodids) per Kilogram of Above-ground Perennial Standing Crop Taken in Cage Sampling, 1976-77

	No. Invertebrates/kg Dried Perennial by Season		
Area	Autumn 1976	Winter 1976-77	Spring 1977
1-3	937	307	460
6	414	385	1110

Cage-study macro-arthropods associated with underground parts of perennials were measured per unit dry weight of the major root systems of *Rhanterium* shrubs and perennials as a whole (Tables 3.4, 3.5).

Table 3.4

Numbers of Subterranean Macro-arthropods per Kilogram Below-ground Perennial Standing Crop Taken in Cage Sampling, 1976-77

	No. Macro-arthropods/kg Dried Vegetation by Season		
Area	Autumn 1976	Winter 1976-77	Spring 1977
1-3	192	112	167
6	228	79	146

For total perennial-associated macro-arthropods, values in both Areas 1-3 and 6 decreased from a maximum in autumn 1976 to a minimum in winter 1976-77 and then showed a moderate increase again in spring 1977. All values per kilogram of perennial root were lower than for above-ground perennial vegetation (Table 3.4).

Table 3.5

Numbers of Subterranean Macro-arthropods per Kilogram Below-ground Rhanterium Standing Crop Taken in Cage Sampling, 1976-77

	No. Macro-arthropods/kg Dried Rhanterium by Season		
Area	Autumn 1976	Winter 1976-77	Spring 1977
1-3	105	67	67
6	134	37	139

Numbers of macro-arthropods per kilogram of below-ground Rhanterium vegetation generally followed trends of below-ground perennials but showed lower values in all seasons and both areas (Table 3.4, 3.5). This indicates that subterranean macro-arthropod production is lower when associated with Rhanterium than with other perennial shrubs.

Species composition above-ground: Table 3.6 shows the number of species sampled in different seasons and areas in 1976 and 1977. Species numbers were higher in Area 1-3 than in Area 6 for all seasons. Generally, there was an increase in species number from autumn to spring (Table 3.6). In comparison with the same seasons in the previous year, both areas showed higher numbers of species for autumn and winter 1976-77 than in 1975-76, but far less numbers of species than in spring 1976.

As in previous years, the high percentage of species unique to seasons and the low percentage shared between seasons indicated that there is a high rate of species turnover during the year. Unique species always constituted over 50% of the species composition in both areas (Table 3.7).

Table 3.6

Number of Invertebrate Species Sampled in Above-ground Cage Samples, 1976-77

	No. of Species by Season			
Area	Autumn	Winter	Spring	Total for Each Area
1-3	51	64	63	33
6	29	31	36	74
Total for Each Season	69	82	81	

Differences between Areas 1-3 and 6 in species composition are emphasized by the large percentage of species unique to these areas and the low percentages shared between them. Species composition of the two areas were most similar in spring 1977. Generally, Area 1-3 had higher percentages of unique species than Area 6, due to overall higher numbers of species (Table 3.8).

Below-ground species composition: Fewer species were sampled below-ground than above-ground in all areas and seasons (Table 3.6, 3.9). There was a general reduction of species from autumn to spring in both areas, a reversal of the above-ground trend. As with above-ground results, more species were found in Area 1-3 than in Area 6 in all seasons (Table 3.9).

For below-ground species, the percentages of unique species did not exceed the percentages of shared species as markedly as in the above-ground sample indicating that turnover of subterranean species, though considerable, is not as high as for above-ground species (Table 3.10).

Table 3.7

Numbers and Percentages of Above-ground Species Unique to, or Shared Between, Seasons for Areas 1-3 and 6 in Cage Sampling, 1976-77

	Species Unique to or Shared with Autumn						Species Unique to or Shared with Winter							
	Unique to Autumn		Shared with Winter		Shared with Spring		Unique to Winter		Shared with Spring		Species Unique to Spring		Species Shared by all Seasons	
Area	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1-3	29	56.9	20	39.2	16	31.4	35	54.7	23	35.9	38	60.3	14	10.5
6	15	51.7	8	27.6	11	37.9	20	64.5	8	25.8	22	61.1	5	6.8

Table 3.8

Numbers and Percentages of Above-ground Species Unique to, or Shared Between, Areas 1-3 and 6 in Cage Samples, 1976-77

	Species Unique to or Shared With Area 1-3				Species Unique to or Shared With Area 6			
	Unique to 1-3		Shared with Area 6		Unique to 6		Shared with Area 1-3	
Season	No.	%	No.	%	No.	%	No.	%
Autumn	40	78.4	11	21.6	18	62.1	11	37.9
Winter	51	79.7	13	20.3	18	58.1	13	41.9
Spring	45	71.4	18	28.6	18	50.0	18	50.0

Table 3.9

Number of Macro-arthropods Samples in Below-ground Cage Samples, 1976-77

	No. of Species by Season			
Area	Autumn	Winter	Spring	Total for Each Area
1-3	22	17	17	37
6	17	16	6	29
Total for Each Season	32	28	20	

As in above-ground samples, there was a marked difference in species composition between Areas 1-3 and 6 in below-ground samples (Table 3.11).

<u>Discussion</u>.-- Values for invertebrates per kilogram of perennial vegetation standing crop cannot be used to compare their abundance on a per-unit-area basis, as differences in plant standing crop between areas and seasons are not taken into account. Two major trends in numbers of species sampled in the different areas and seasons in above-ground cage samples in 1976-77 were:

(1) The predominance of species in Area 1-3 compared to Area 6.
(2) The low numbers of species in spring 1977 compared to spring 1976.

The influence of heavy, year-round grazing in Area 6 probably accounts for the low number of species sampled there in comparison with the non-grazed Area 1-3. The low precipitation value (68.6mm) for 1976-77 compared to that in 1975-76 (497mm) probably accounts for the greatly reduced variety of species sampled in spring 1977, after record numbers in spring 1976. With the reduced precipitation, a correspondingly reduced spring vegetation production probably resulted in unfavorable trophic conditions for many species which had been present in 1976. Drier microenvironments might also account for the failure of many pre-adult forms to develop.

The high turnover of species from season-to-season has been noted since the beginning of the study in 1973. A lengthy discussion of turnover may be found in the 1976 Annual Report in the Activity Section, headed "Temporal Trends in Populations of the PreSaharan Fauna."

Table 3.10

Numbers and Percentages of Below-ground Species Unique to, or Shared Between, Seasons for Areas 1-3 and 6 in Cage Samples, 1976-77

	Species Unique to or Shared with Autumn						Species Unique to or Shared with Winter							
	Unique to Autumn		Shared with Winter		Shared with Spring		Unique to Winter		Shared with Spring		Species Unique To Spring		Species Shared by all Seasons	
Area	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1-3	9	40.9	9	40.9	9	40.9	7	41.2	6	35.3	7	41.2	5	13.5
6	12	70.6	5	29.4	3	17.6	9	56.2	5	31.2	1	16.7	3	10.3

Table 3.11

Numbers and Percentages of Below-ground Species Unique to, or Shared Between, Areas 1-3 and 6 in Cage Sampling, 1976-77

	Species in Area 1-3				Species in Area 6			
	Unique Species		Species Shared with Area 6		Unique Species		Species Shared with Area 1-3	
Season	No.	%	No.	%	No.	%	No.	%
Autumn	15	68.2	7	31.8	10	58.8	7	41.2
Winter	12	70.6	5	29.4	11	68.7	5	31.3
Spring	14	82.4	3	17.6	3	50.0	3	50.0

Below-ground sample results probably reflect the life "style" and form of the subterranean species. The degree of protection from extremes and fluctuations in micro-climate afforded by a subterranean environment has probably contributed to the lower rate of species turnover generally found below-ground compared with above-ground turnover. The fact that many of the subterranean species are pre-adults which emerge in spring as adults might explain the reduction in number from autumn to spring.

Estimation of Numbers and Biomass for Large Adult Coleoptera

The large Coleoptera of the families Tenebrionidae and Carabidae are not adequately sampled by cage or sweep methods. These are active foragers on the soil surface and live beneath the surface when not active. Both at times of activity and nonactivity, their distribution is largely independent of perennial shrubs. Due to irregularities in foraging behaviour, direct counts are not considered an effective measure of total coleopteran numbers. Thus a capture/recapture marking technique has been applied to estimate density and hence, biomass of the group.

Methods.-- The method used differs little from that described in the 1975 Annual Report and will only be outlined briefly here. In autumn 1976, winter 1976-77 and spring 1977, the number of large Coleoptera was estimated in 20 x 40 m plots in Areas 1-3, 6 and 7 (1-3 spring-grazed). The plots in Areas 1-3 and 6 were studied in each season, while Area 7 was only begun in spring. Two methods of estimation were applied: (1) The Schnabel capture/recapture technique, and (2) linear regression of numbers marked at large against new captures. A mean was taken of the two estimates to give the final estimation. This allowed for the conservative bias of the linear regression method and the over-estimation possible with the Schnabel method if marking deterred recapture. When no recaptures were made the regression was accepted as the population estimate.

The study was conducted over a 48 hr period each season with six different capture and marking periods for each area. The marking periods were allotted to cover a wide range of the 24 hr cycle so that all species of different temporal activity patterns might be included in the estimates. From the estimates of number per plot, the number per hectare and dry weight per hectare were calculated.

Results.-- The following species were sampled in 1976-77:

Family Tenebrionidae, primarily herbivores

1. *Blaps* sp. Cat. No. 706
2. *Pimelia obsoleta* Cat. No. 641
3. *Pimelia* sp. Cat. No. 641D
4. *Pimelia* sp. Cat. No. 641C
5. *Scaurus braviatus* Cat. No. 804

Family Carabidae, primarily scavengers and carnivores

6.	Anthia maculata	Cat. No. 640
7.	Craphopterus serrator	Cat. No. 645
8.	- -	Cat. No. 1004
9.	- -	Cat. No. 1549

As in 1975 and 1976 the number and biomass of plant-ingesting Tenebrionids greatly exceeded those of the Carabids in all areas and at all seasons (Table 3.12). Blaps was predominate in both Areas 6 and 1-3 in autumn and its number and biomass in this season exceeded those in the other two seasons (Table 3.12). In winter, number and biomass generally decreased in both Area 6 and 1-3 mainly due to the absence of Blaps. Pimelia obsoleta (641) was the only species recorded in winter and was numerous in Area 1-3 where it showed maximum population and biomass values for the 1976-77 study (Table 3.12). In spring there was an increase in numbers and biomass of Coleoptera in both Areas 1-3 and 6, mainly due to the reappearance of Blaps. Pimelia obsoleta remained at high level, exceeding biomass of Blaps in Areas 6 and 7 (Table 3.12). Pimelia obsoleta was the dominant Pimelia species throughout except in spring in Area 7 (1-3 spring-grazed), where the nocturnal 641D was predominant.

Tenebrionid biomass values were combined to compare the areas and seasons (Fig. 3.1). Area 1-3 supported a higher tenebrionid biomass than Area 6 except in spring. The only result for Area 7, in spring, yielded higher biomass values than Area 1-3 and Area 6 at any season. Both Areas 1-3 and 6 showed highest biomass in autumn, a decline to a minimum in winter and an increase in spring (Fig. 3.1).

Therê has been a considerable reduction in Tenebrionid biomass since records taken in 1975-76. This was most marked in Area 1-3. The decrease was registered in both Blaps and Pimelia species except in winter when Pimelia obsoleta was generally higher in (1977).

Discussion.-- Results in 1976-77, again support those of other years in that there is an alternation of domination between Blaps and Pimelia over the annual cycle. Pimelia dominates in winter and spring, while Blaps dominates the autumn sample. Though no results are yet available for summer 1977, it is expected that Blaps will dominate as it did in 1975 and 1976 (Progress Reports 4 and 5). Results must still be corrected for migration rates before final publication. With most species which do not forage widely and/or always return to the same hole or refuge site, the correction will be almost negligible. However, with the important Pimelia obsoleta, the correction will be considerable as they range over large distances and dig into any suitable site near them when they seek refuge. Studies have been undertaken to estimate spatial displacement per unit time for Pimelia obsoleta and other common species. These results will be interpreted in terms of a migration rate so that correction can be made to population estimates.

Table 3.12

Estimated Numbers and Biomass of Large Coleoptera Species, 1976-77

		No. Individuals and Biomass by					
		Autumn		Winter		Spring	
Area	Species Cat. No.[1]	No./ha	Gm/ha	No./ha	Gm/ha	No./ha	Gm/ha
1-3	706T	1288	319.4	—	—	526	130.4
	641T	187	98.5	261	137.5	188	99.1
	641DT	12	3.1	—	—	12	3.1
	804T	12	1.3	—	—	—	—
	645C	25	1.1	—	—	—	—
	1549C	—	—	—	—	25	3.6
	640C	—	—	—	—	12	2.6
6	706T	1243	308.3	—	—	470	116.6
	641T	25	13.2	12	6.3	258	136.0
	641DT	—	—	—	—	12	3.1
	641CT	—	—	—	—	12	2.4
	1549C	25	3.6	—	—	25	3.6
	1004C	—	—	—	—	12	7.8
	640C	—	—	—	—	12	2.6
	645C	12	0.5	—	—	—	—
	804T	12	1.3	—	—	—	—
7	706T					345	85.6
	641T					199	104.9
	641DT					923	237.2
	1549C					212	30.7
	645C					125	5.6
	640C					12	2.6

[1] T denotes Family Tenebrionidae, C denotes Family Carabidae

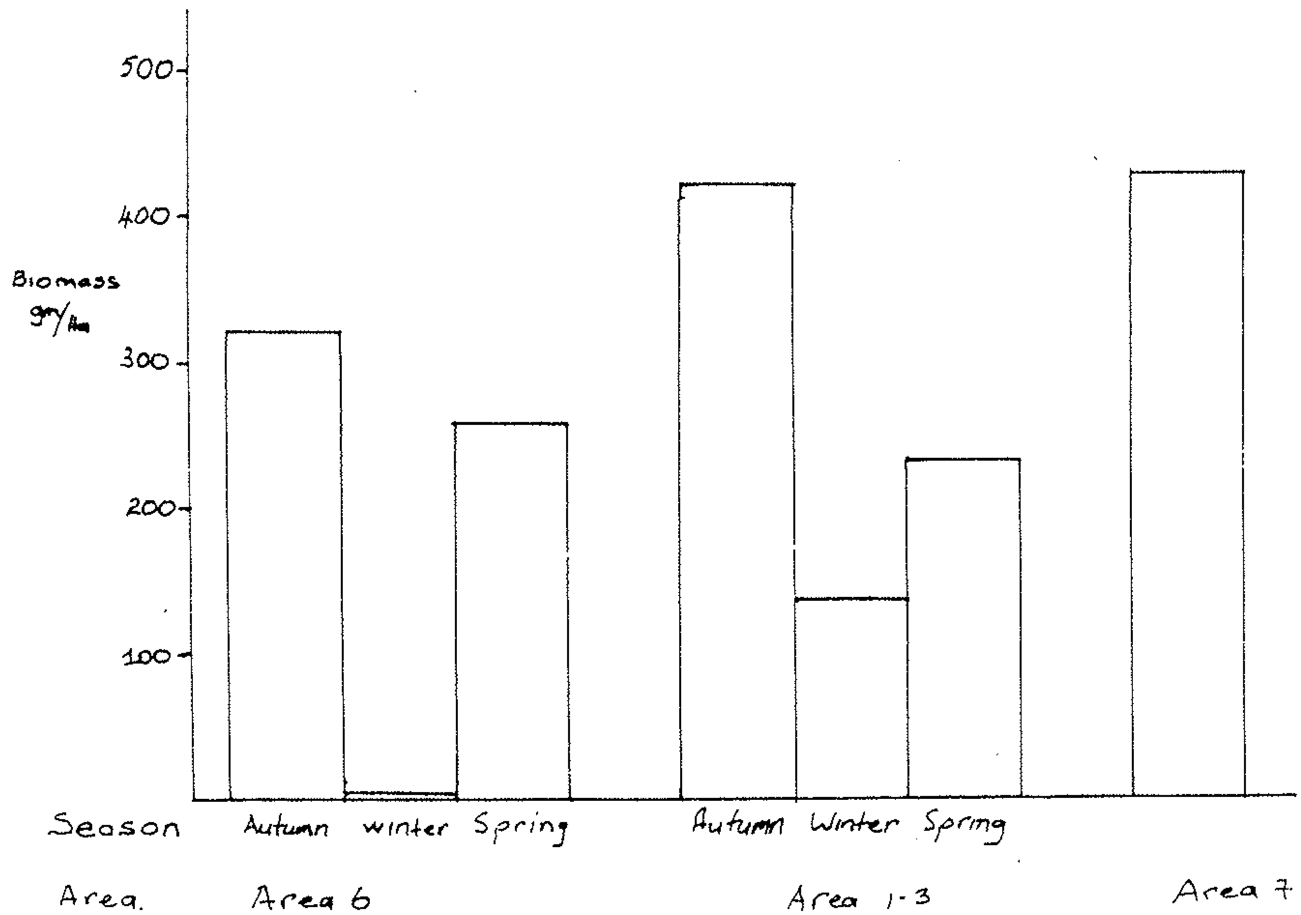


Figure 3.1. Combined biomass of adult Tenebrionid population estimated in Areas 1-3 and 6 in autumn, winter and spring (1976-77) and in Area 7 in spring 1977.

Ant Population and Biomass Estimation

Another important insect group which cannot be adequately sampled by the cage or sweep methods is the ant group. This sampling difficulty is due to their surface foraging habit and subterranean refugia, as with the large Coleoptera. Thus a supplementary method is required: Colonies are excavated to determine numbers of individuals per colony, and dry weight of individuals of each caste type. Colony numbers per hectare for each species are determined and the number of individuals per hectare and biomass per hectare are estimated.

As outlined in the 1975 Progress Report, the active colony has been accepted as the basis for measuring ant density per unit area. Hence the number and biomass of those ants influencing the ecoysstem at the particular sampling time are determined, and not the total biomass which would include dormant colonies.

Method.-- The ant sampling method used in 1976-77 is identical to that used in 1975, in spring and summer and may be found in the 1975 Progress Report. A brief outline will be given here. In the same 20 x 40 m sub-areas used for the Coleoptera population study, active colonies of ants were mapped in autumn, winter and spring 1976-77. Colonies of all species were mapped in autumn and winter and only the harvesting ants in spring. Areas 1-3 and 6 were mapped in all seasons whereas Area 7 was mapped only in spring. The mapping was conducted over a wide range of the diel cycle, to allow for ant species of different foraging times. Baits were used to help trace colonies. Number of colonies per hectare was calculated from the mapped areas. Using available data on number of individuals per colony and dry weights of individuals of different size castes, population and biomass per hectare were calculated for each species. When the number of individuals per colony had not been measured, estimates were made and substituted to calculate population and biomass.

Results.-- The species sampled in this study may be seen in Table 3.13, along with excavated and estimated values for numbers of individuals per colony. Also shown are mean dry weights for workers of each species calculated from random samples of 50 workers. Total biomass for the harvesting ants and all other ants combined was calculated for each season and each area for comparison purposes (Fig. 3.2).

In all areas and seasons the largest contribution to biomass was from the large-sized ants such as *Messor A* (748), *Messor B* (741), *Cataglyphis* (653) and Cat. No. 630 (Tables 3.13, 3.14). In most areas and seasons the most common ants, in terms of colonies per hectare, were Cat. No. 684 and *Messor B*. The most dominant ant in terms of individuals per hectare, and biomass, was *Messor B*, due to its large number of colonies per hectare and its large number of individuals per colony (Table 3.13, 3.14).

The two harvesting ant species, *Messor A* and *Messor B*, made up the majority of the ant biomass in all seasons and areas, showing more than double the biomass of all other ant species combined (Fig. 3.2).

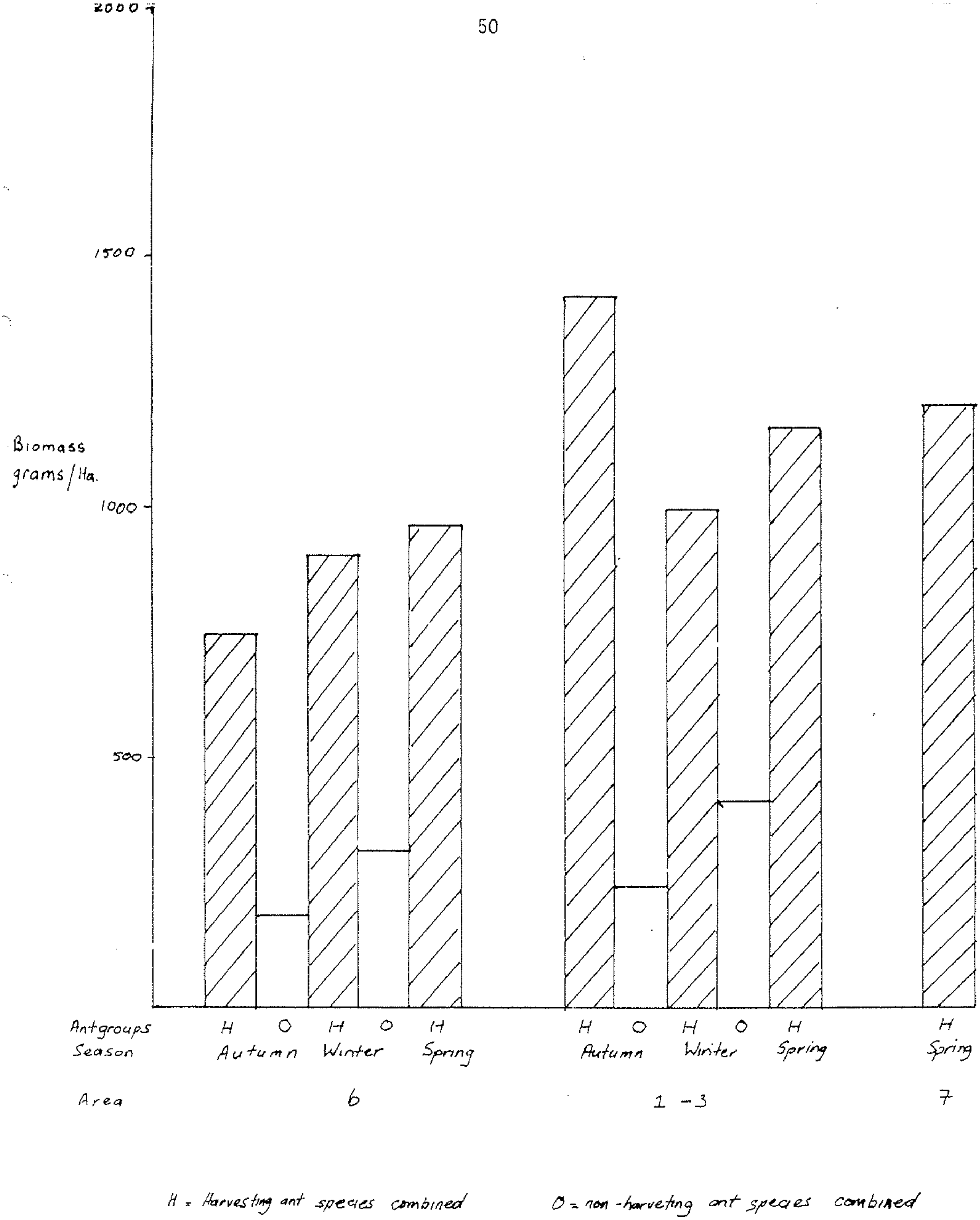


Figure 3.2. Biomass of the harvesting ant species combined and all other ant species combined in autumn, winter and spring (1976-77) in Areas 1-3, 6 and 7.

Comparing soil surface area types it may be seen that a higher ant biomass was recorded in the non-grazed Area 1-3 than in the heavily grazed Area 6, in all seasons. In both areas there was a trend of increasing biomass from autumn to spring samples with one exception: The harvesting ant biomass in autumn in Area 1-3 was higher than that of winter or spring (Fig. 3.2).

In comparing results with 1975-76 results (Progress Report No. 5), it may be noted that in 1976-77, biomass in Area 1-3 was similar to that in 1975-76 but, in Area 6, 1976-77 biomass was lower than in 1975-76. This decline could be attributed to the low rainfall in 1976-77 and the effects of grazing.

Table 3.13

Number of Individuals per Colony and Mean Weight per Individual of 12 Ant Species

Species	Cat. No.	Number of Individuals per Colony			Mean Dry Wt. of Workers (g)
		Excavated	Estimated	Mean	
Messor A	748	783,700		741.5	.00664
Messor B	741	6,235		6,235	.00099
Monomorium	601	1,238, 5,840		3,539	.00021
Cataglyphis	653	3,379, 4,973		4,176	.00227
Cataglyphis	673		700	700	.00086
	630	2,076		2,076	.00362
	606		1,400	1,400	.00049
	684	898,596		733.5	.00018
	795		650	650	.00012
	1601		350	350	.00005

Snail Population and Biomass Studies

Subterranean habitat as a refuge for snails.-- In the 1976 Report (No. 5), snail populations were estimated by means of a capture-recapture method on the assumption that at any one time, but particularly in seasonal and daytime heat extremes, part of the adult snail population seeks refuge underground. This assumption was supported by the appreciable recruitment and loss of snails to and from the marked populations.

Method: In May 1977, 10 plots of 1 m^2 each were selected randomly within areas of high snail concentration. These plots were excavated to a depth of 30 cm and the soil was sieved through a 2mm sieve.

Results: From the 10 m^2 which supported a population of 104 live snails above the ground on plant foliage, not a single live snail was found by sieving soil (Table 3.15). Thus capture-recapture techniques for estimation of population have been rejected as a method of estimating population and biomass. Total counts of living snails above ground have been accepted as the population of snails at the time of the count.

Table 3.15

Snails (Cat. No. 660) Found Above and Below Ground on 10, 1 Square Meter Plots[1]

	No. Live Snails		No. Dead Snail Shells	
Plot No.	Above-ground	Below-ground	Above-ground	Below-ground
1	13	—	—	—
2	2	—	—	—
3	21	—	—	1 small
4	4	—	—	—
5	2	—	—	2 small
6	3	—	—	3 small
7	17	—	3	—
8	2	—	—	—
9	6	—	1	—
10	34	—	1	—

[1] Soil sieved with 2mm sieve to 30 cm depth.

Snail dry weight.-- In 1976-77, a large number of young, rapidly growing snails were recruited into the snail population. Large variations in snail size over the seasons made it difficult to assign weight values for calculating biomass. A method was devised to estimate bimass, allowing for varying snail sizes at each different sample.

Method: Beginning May 13, 1976, shell diamter was measured for all snails in the total-count population estimation. To estimate dry weight of snails in the population count, a dry-weight/shell-diameter regression was constructed so that an estimate of dry weight could be easily obtained for any shell size (Fig. 3.3). The regression was calculated for 153 snails, selected for size variation on May 28. These were oven dried, weighed and measured for shell diameter (Fig. 3.3).

Results: The regression followed a power curve $y = 18 x^{2.61}$ with a resolution of $r^2 = .97$ (Fig. 3.3). Some of the largest old snails did not fit the curve well and the shell diameter appears to follow a linear regression after a certain size or age is reached. This has not been allowed for in this account but will be included in biomass calculations for final publication of results. Biomass was calculated by substituting dry weight corresponding to the mean shell diameter of each snail group studied in the population study. Thus biomass calculation makes an allowance for different size structures in the snail population.

Estimation of Snail Population and Biomass.--

Method: In the four sub-areas used for the ant and beetle studies, snails were counted periodically starting in April 1976. Counts were conducted every 2 weeks until June. By June many snails were inactive and, to avoid influencing survival by the frequent removal of snails from vegetation, the counts were conducted once a month until the end of 1976. In 1977 counts were conducted at intervals of between 1 and 2 months. Population at each count time was estimated for each area per hectare (Table 3.16).

Over the same period total counts of snails were conducted in a 30 x 5 m transect. Monthly population estimates per ha for the transect snails were calculated for comparison with the four soil-surface types sampled for population and biomass (Table 3.17).

Starting on May 3, 1976, all snails counted in population estimations were measured for shell diameter. At each sample new recruits were marked a different color, thus giving several colors at each sample. Each color group was treated as a unit in shell diameter measurements. To calculate biomass, dry weights corresponding to the mean shell diameter of each snail group were taken from the dry-weight/shell-diameter regression curve (Fig. 3.3). Total dry weight of each snail group was calculated and results for all groups in each area were combined. Biomass was then

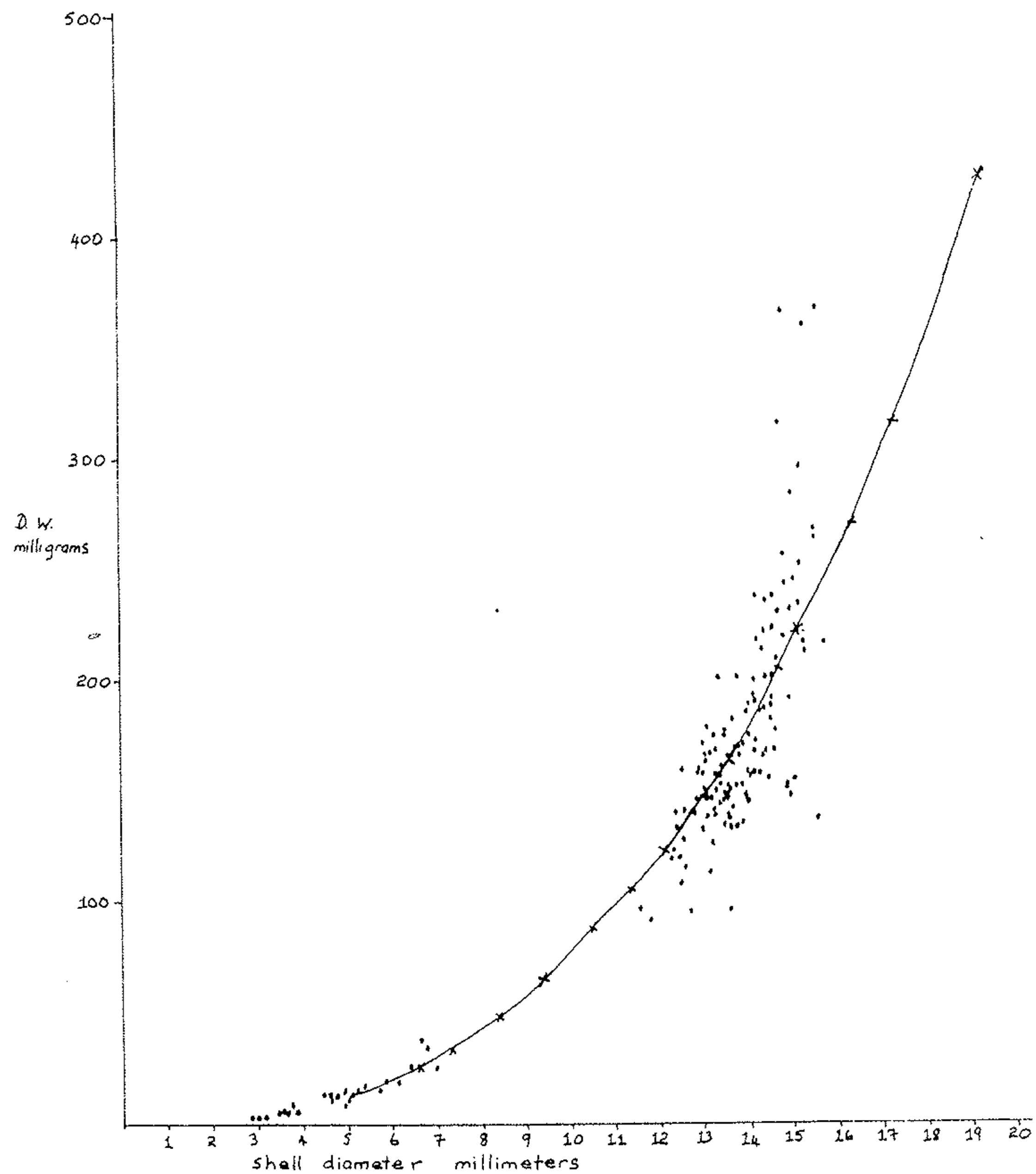


Figure 3.3. Regression of dry weight on shell diameter of 153 snails (Cat. No. 660) selected for maximum size variation 5/28/77.

Table 3.16

Snail Population and Biomass per Hectare in Four Areas Studied in 1976 and 1977

	Area 1-3		Area 6		Area 4		Area 5	
Date	No./ha	Biomass Gm/ha	No./ha	Biomass Gm/ha	No./ha	Biomass Gm/ha	No./ha	Biomass Gm/ha
4/1/76	37.5	9.0	1925	462.0	0	0	387.5	93.0
4/13/76	50.0	12.0	1987.5	477.0	0	0	762.5	183.0
4/27/76	50.0	12.0	2162.5	519.0	0	0	437.5	105.0
5/13/76	62.5	15.9	2487.5	538.7	0	0	650.0	163.2
5/23/76	62.5	17.4	2062.5	463.7	12.5	3.5	712.5	190.1
6/21/76	87.5	21.7	1637.5	408.7	12.5	3.6	412.5	121.0
7/24/76	75.0	19.4	1337.5	370.9	25.0	6.5	550.0	136.1
8/23/76	62.5	17.0	1137.5	331.2	37.5	10.1	450.0	119.6
9/10/76	62.5	17.9	912.5	248.4	37.5	9.6	362.5	95.9
10/28/76	625.0	47.2	6550.0	515.2	50.0	11.4	9150	410.63
11/26/76	612.5	42.6	8200.0	577.0	75.0	7.9	9462.5	529.5
1/11/77	1100.0	142.6	7725.0	880.1	50.0	9.5	15900.0	1750.9
3/2/77	1800.0	364.6	5137.5	980.6	50.0	10.4	12775.0	2394.7
5/3/77	1137.5	280.7	3462.5	732.5	50.0	9.2	9762.5	1943.1

calculated per ha (Table 3.16).

For those counts taken before May 13, biomass was calculated from the mean dry weight of a random selection of ten adult snails. For transect results, after May 13, mean weights for snails in Area 1-3 were substituted at each sample time to calculate transect snail biomass (Table 3.17). Area 1-3 was chosen in preference to other areas as about 75% of the transect consists of Area 1-3 type soil surface.

Population results: Table 3.16 shows the pattern of snail population throughout the year, and the time of detectable increase. Generally, the population showed a decline through summer, followed by a large increase in autumn. The population reached a peak in winter and then began to decline again through spring towards summer (Table 3.16, Fig. 3.4). All four areas showed an increase in population in spring 1977 from spring 1976. The most marked increases occurred in Areas 5 and 1-3, both ungrazed areas. Area 6, heavily grazed, showed only a moderate increase on the already substantial population of 1976. Area 4, the original sand dune area, increased from zero population in spring 1976 to a small population in 1977 (Table 3.16, Fig. 3.4). Comparing the absolute populations of the four areas reveals that the population in Area 5 now exceeds the population in Area 6 which was the highest in 1976, (Table 3.16, Fig. 3.4).

Transect results showed a similar sharp increase in population in autumn as for the four population sample areas. Absolute population was of a magnitude between that of Area 1-3 and Area 6 (Table 3.17, Fig. 3.6).

Biomass Results: Generally the biomass results were similar to the population results (Table 3.16, Figs. 3.4, 3.5). There was a decline in summer and a sharp increase in autumn. However the biomass results exhibited differences imparted by the structure of the population in terms of size classes. The biomass increased at a slower rate than the population in autumn and reached a peak in early spring after the population had reached a winter peak (Table 3.16, Figs. 3.4, 3.5). This was due to the growing period of new recruits first detected in large numbers in autumn. These grew throughout winter and spring. Thus, biomass increased slowly at first and continued to grow after the population decreased, due to weight increases in the new recruits. This is best demonstrated in Fig. 3.6, where the population and biomass of transect snails are shown together.

Snail population structure and growth rate study.--

Method: Beginning on May 13, 1976, the shell diameter of all snails counted in the population study in Areas 1-3, 4, 5 and 6 were measured with a vernier caliper. The snail was measured with the coil facing the measurer and the rim of the snail aperture parallel to the axis of the vernier caliper (Fig. 3.7). New snails captured at each count were marked with nail lacquer and measured shell diameters were grouped according to the mark type. Thus, each new recruitment of snails at each

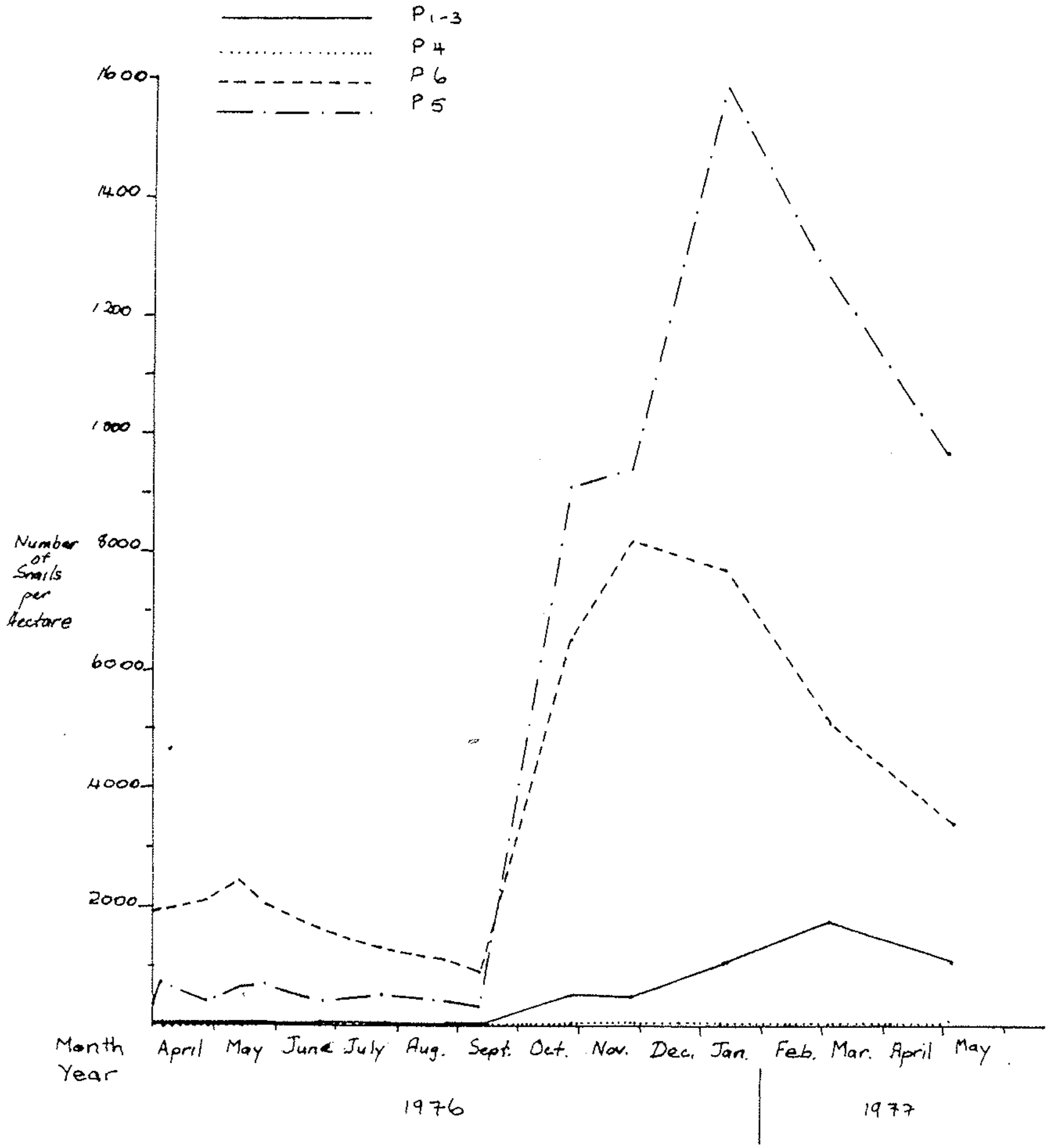


Figure 3.4. Snail density per hectare in Areas 1-3, 4,5 and 6. Measured from April 1976 to May 1977.

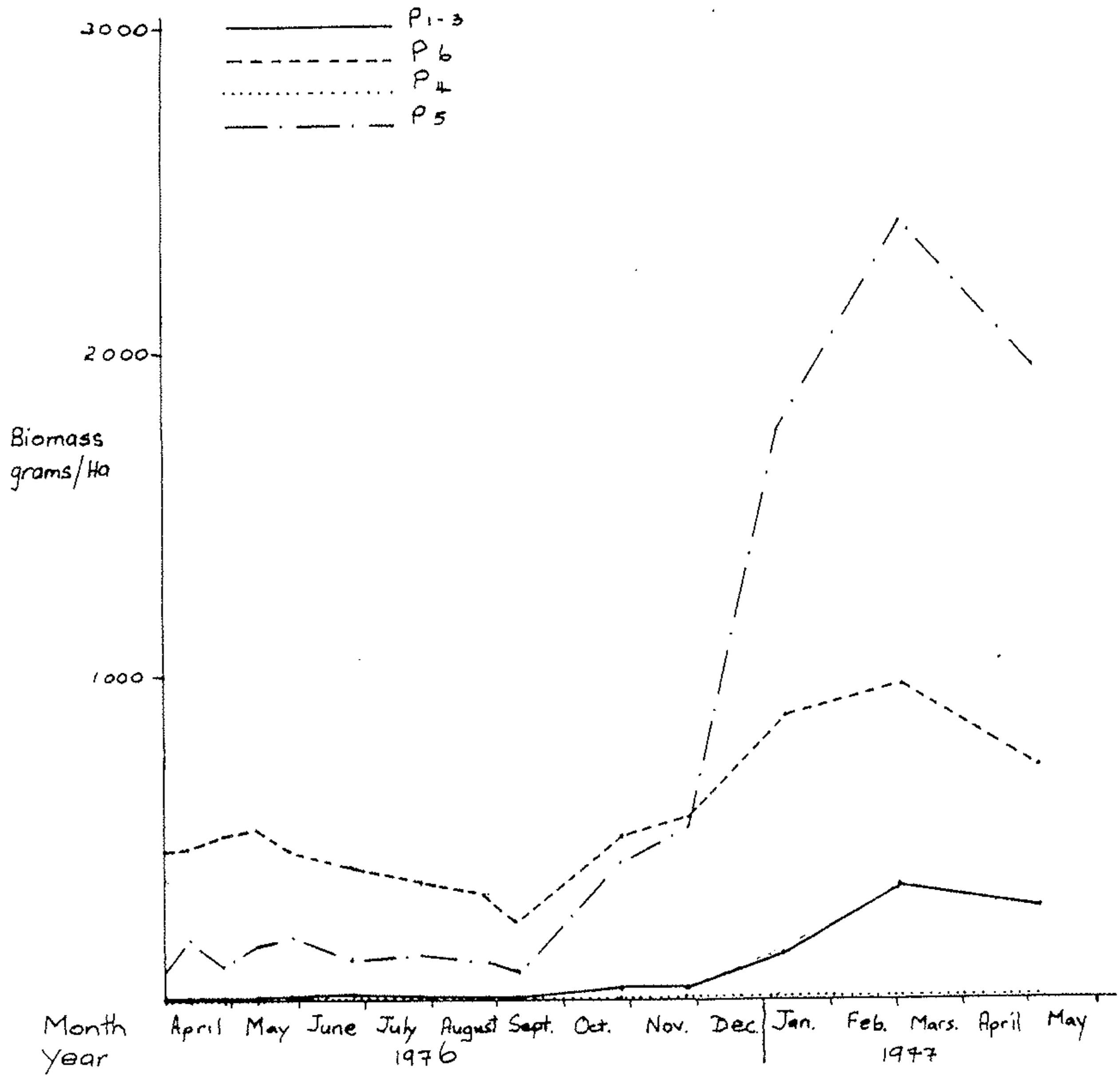


Figure 3.5. Snail biomass per hectare in Areas 1-3,4,5 and 6 measured from April 1976 to May 1977.

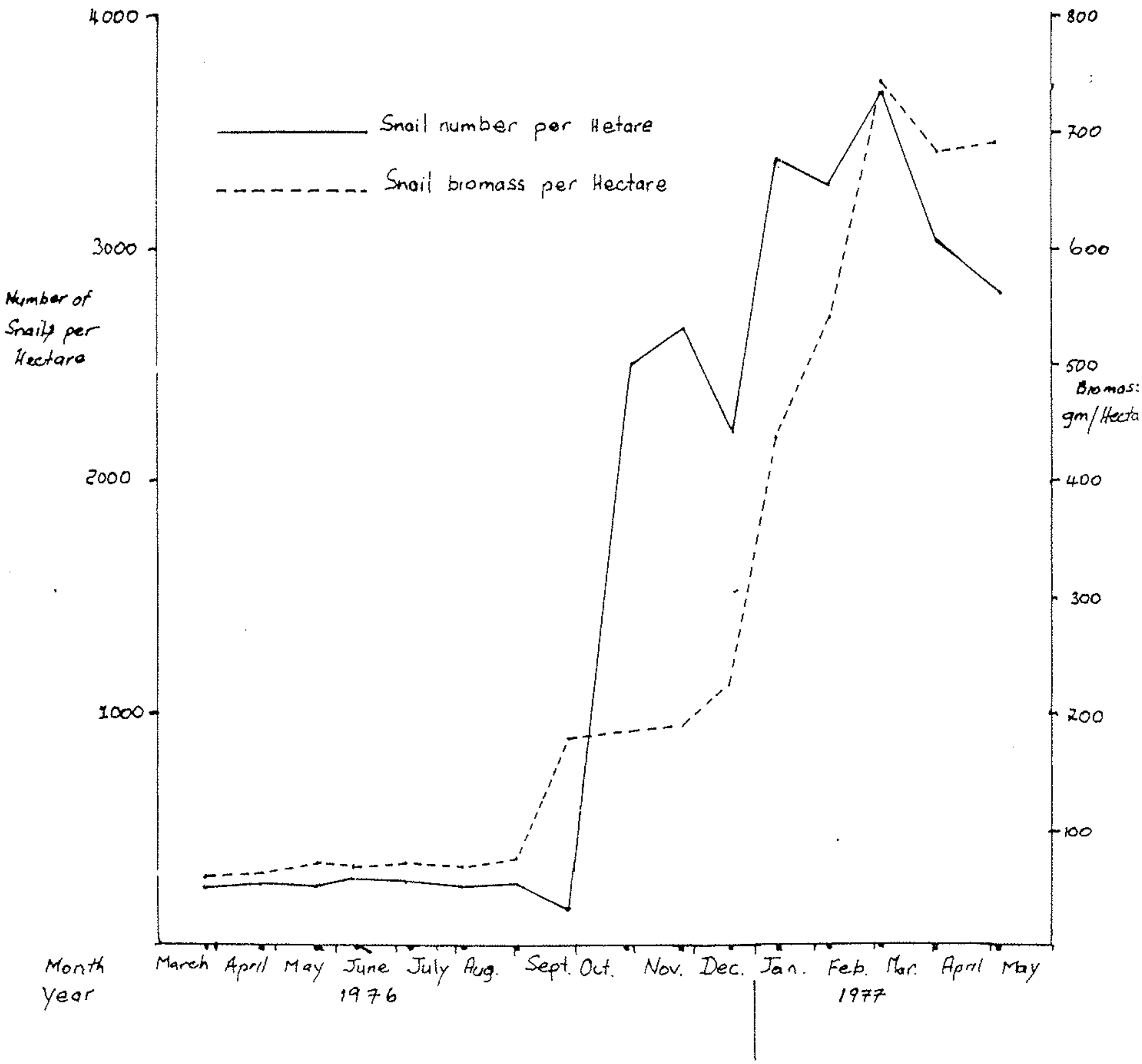


Figure 3.6. Snail density and biomass per hectare measured in a 320x5 meter transect from March 1976 to May 1977.

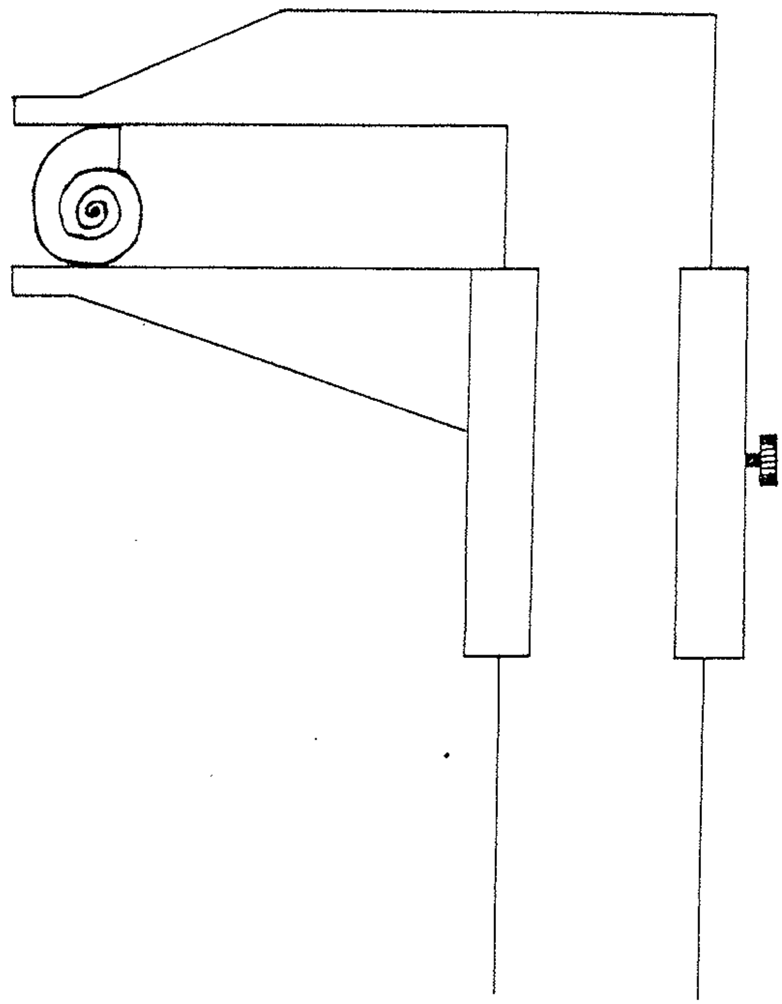


Figure 3.7. Technique for measuring snail diamter.

count was followed in growth in subsequent counts. Mean shell diameterand standard error of the mean were calculated for each snail group at each count.

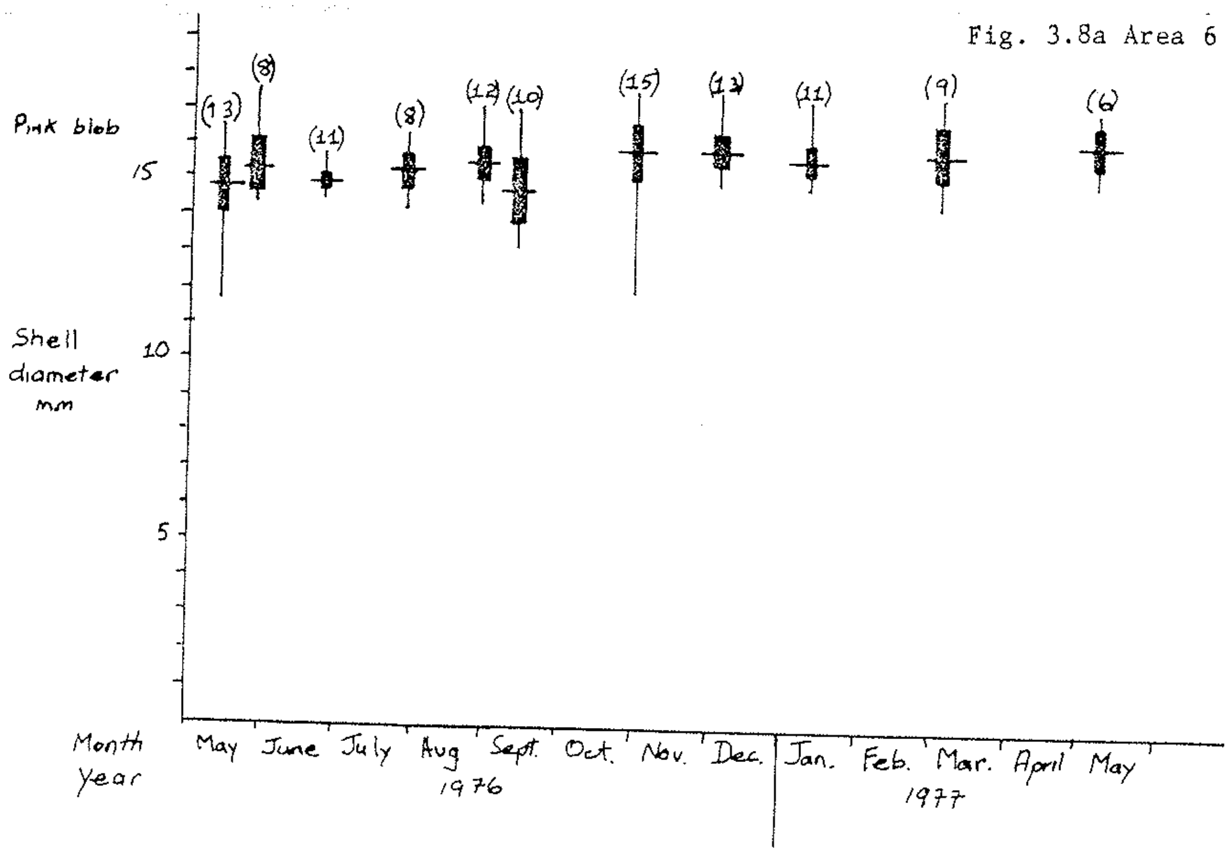
For this report results in their entirety will not be shown. To demonstrate the pattern of growth in the snail population, only results from Areas 5 and 6 will be displayed, and only two population groups in each of these areas will be followed. These are, Pink Blob, the initially marked population (January 1976), and Red Stripe 1, marked November 26, 1976 after recruitment of young snails (Figs. 3.8, 3.9).

Behavior patterns of the snail populations were recorded and incorporated in an outline of the life cycle of the snail, Cat. No. 660.

Table 3.17

Snail Population and Biomass per Hectare Taken from Transect Samples, 1976-77

Month	Year	Population No./ha	Biomass Gm/ha
March	1976	250	60.0
April	1976	262.5	63.0
May	1976	256.25	71.3
June	1976	281.25	69.7
July	1976	275.0	71.1
Aug.	1976	256.25	69.7
Sept.	1976	262.5	75.1
Oct.	1976	2518.75	180.4
Nov.	1976	2668.75	185.7
Dec.	1976	2212.5	221.2
Jan.	1977	3381.25	439.5
Feb.	1977	3281.25	541.4
Mar.	1977	3675.0	744.4
April	1977	3043.75	684.8
May	1977	2806.25	692.5



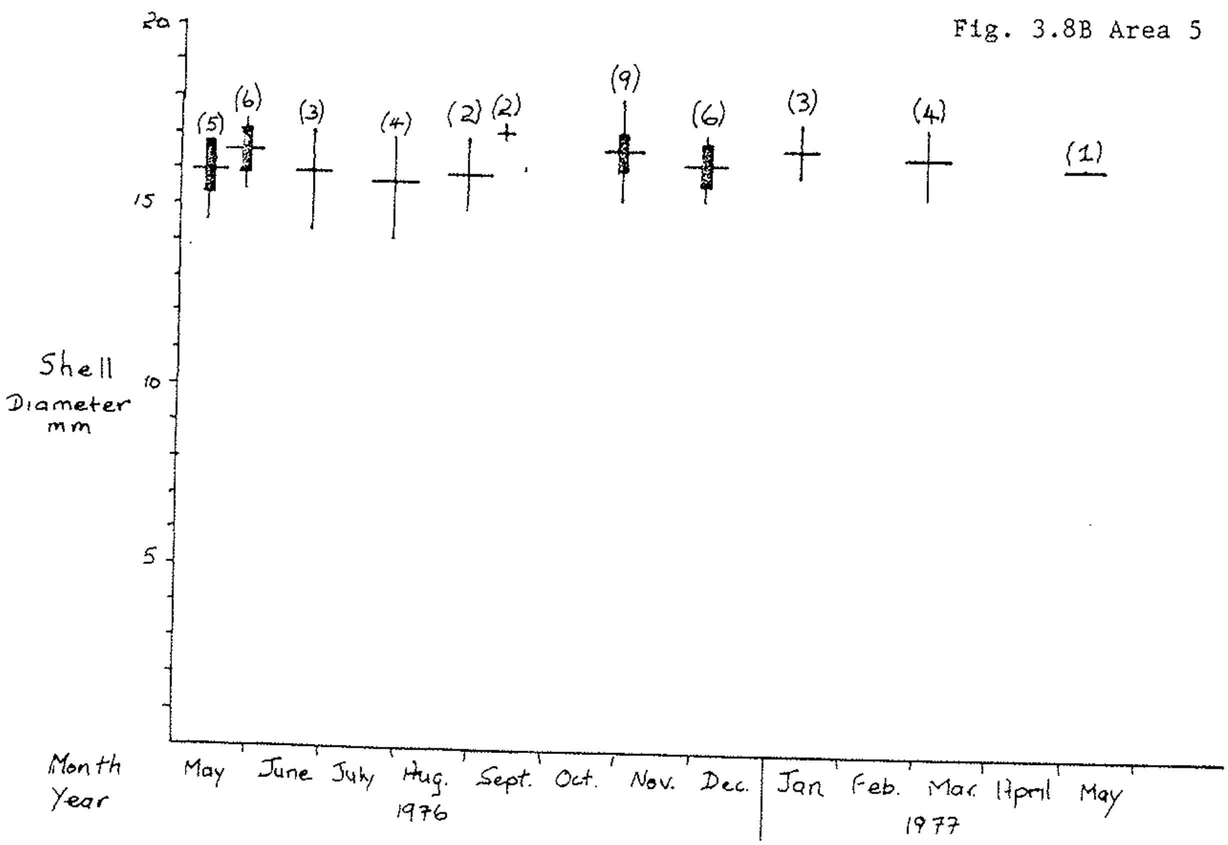
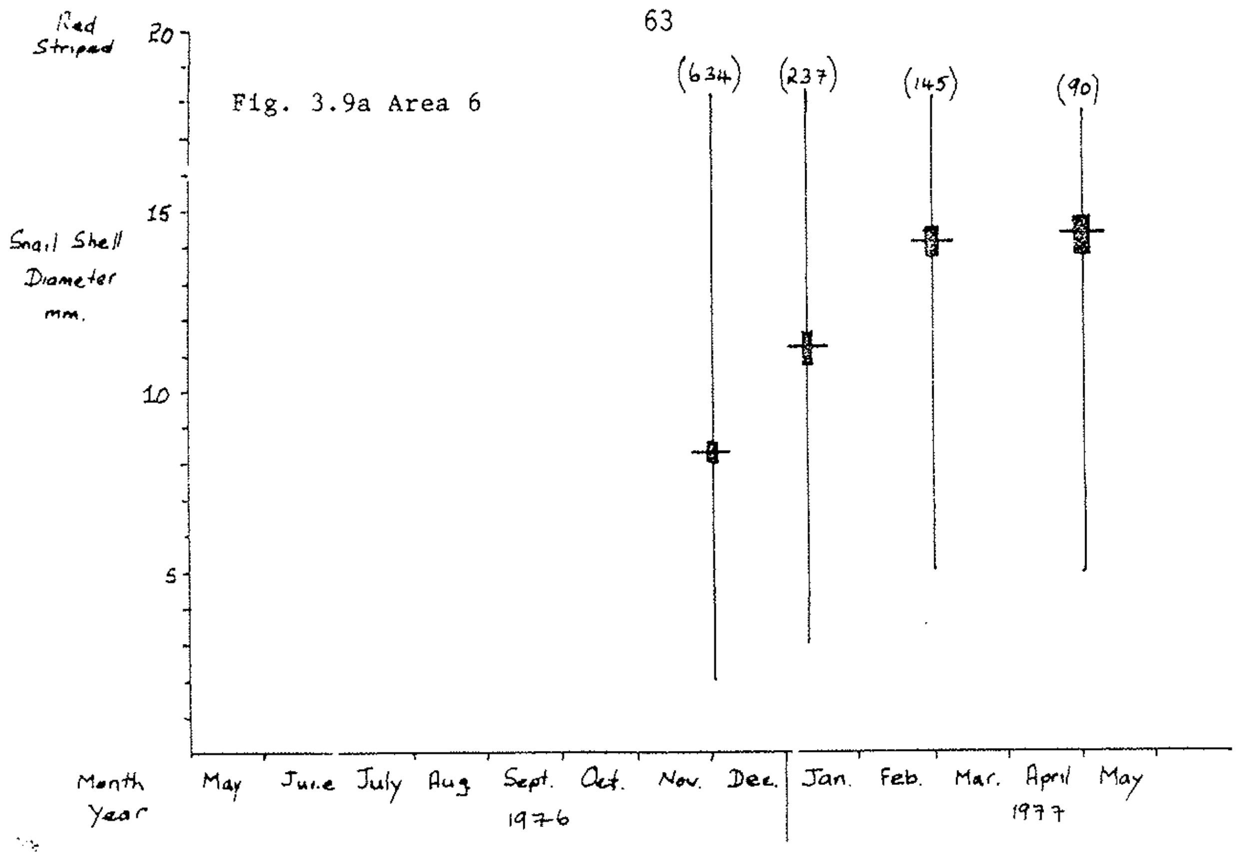


Figure 3.8. Mean, two standard errors of the mean and range of snail shell diamters of the adult populations (marked Pink Blob) present in January 1976 in Areas 6 and 5, studied from May 1976 to May 1977 (8a Area 6, 8b Area 5). Sample sizes are indicated in parentheses.



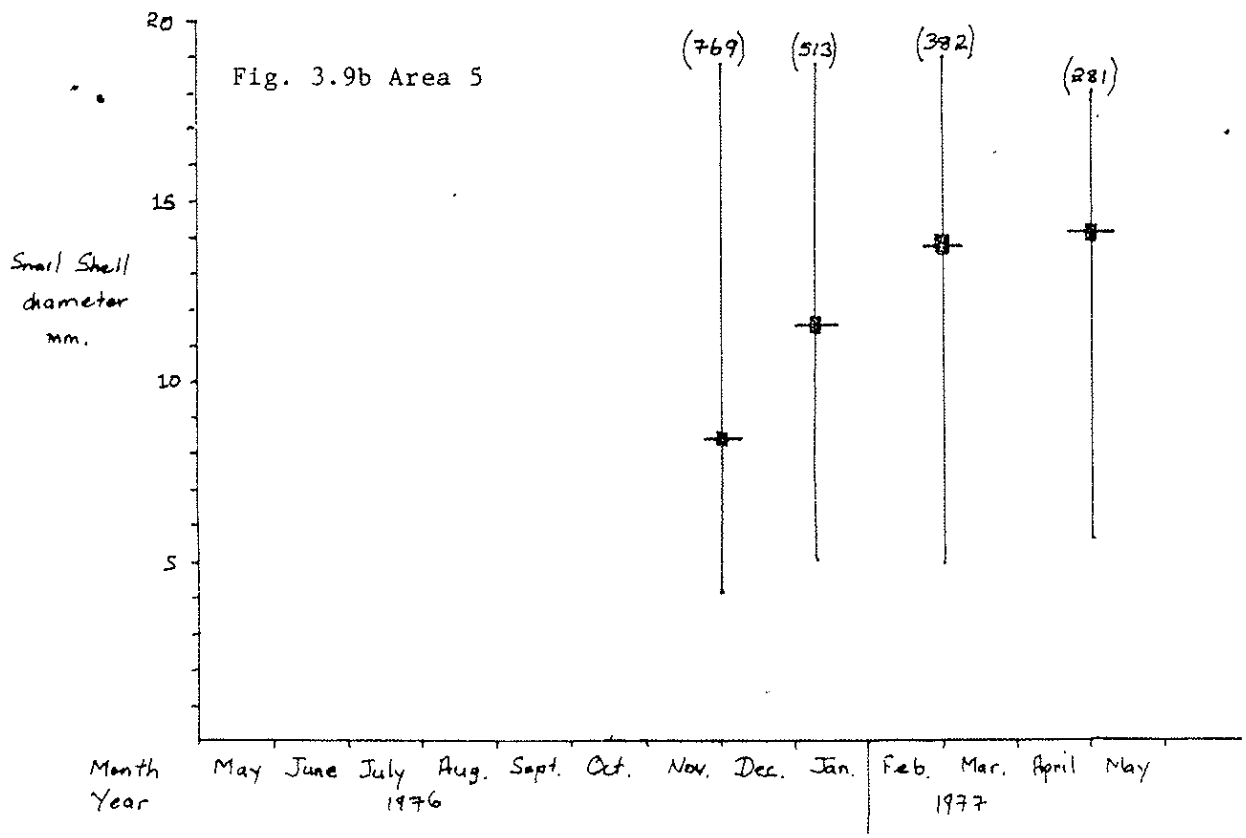


Figure 3.9. Mean, two standard errors of the mean and range of snal shell diameters of the populations (marked Red Stripe) recruited in Autumn 1976 in Areas 6 and 5, studied from November 1976 to May 1977 (9a Area 6, 9B Area 5). Sample sizes are indicated in parentheses.

Results: Adult snails were observed copulating after rain in the daytime, and at night during conditions of high humidity, in early November 1976. Eggs were deposited in holes dug in the moist sand at rainy or humid periods between late December and mid-February. The new generation produced will not be detected in large numbers in the above-ground population until autumn 1977. The populations followed in this study were those adults present in early 1976 (Pink Blob), and those recruited in autumn of 1976 (Red Stripe 1).

Figure 3.8, a and b, shows the mean, two standard errors and the range of shell dimater for the initially marked adult population (Pink Blob) in Areas 6 and 5 respectively. At each measurement of the population there was little change in the shell diameter. Significant differences (to .05 level) were found only between measurements of the populations well separated in time. For example, Area 6 June 1976 results differed significantly from those in December 1976, January and May 1977 (Fig. 3.8a). Generally, there was a gradual slight increase in size in the populations over the period of study (Fig. 3.8a, b).

For the populations recruited in October (Red Stripe), there was a rapid increase in shell diameter in sucbessive measurements in both areas (Fig. 3.9a, b). Measurements taken in December 1976, January and March 1977 were all significantly different (to .05 level) from one another. The only measurements not significantly different were taken in March and May 1977 in both areas (Fig. 3.9a, b).

Discussion: From studies to date, it is apparent that the snail (Cat. No. 660) life cycle begins with copulation late in autumn and early winter. Eggs are deposited in the ground in winter. The majority of the young generation remains underground through spring and summer and does not emerge until the first rains of autumn. There follows a period of rapid growth through autumn, winter and spring. The snails then pass their second summer attached to the stems of perennial shrubs. Survivors in autumn are then ready for reproduction. It is not known how many years a generation will continue, but it is thought that if conditions were good, snails could continue over 3 years, showing only a slow growth rate after reaching sexual maturity.

The soil-sieving study suggests that few or none of the mature snails seek a subterranean refuge from the hot summer conditions or from predators. Thus, apparent fluctuations in marked populations are probably due to problems with the marking technique or migration during rainy periods and in the humid pre-sunrise period. Predation might also account for rapid reduction in numbers of a marked population. Ants and rodents will carry off snail prey whereas others tend to leave the empty shell attached to the bush. Much of the predation noted has occurred in summer 1977, which has not been included in this account. A full evaluation of predators and their influence will be included in the next report.

In the dry-weight/shell-diameter regression conducted May 28, 1977; the collected snails fell into two main groups (Fig. 3.3): A group between 2 and 7mm diameterand another from 11 to 18mm. The smaller group represents the new generation of developing snails produced in 1977, and the larger group represents the previous generation (studied in the growth-structure study), plus mature adults from earlier years. The numbers of smaller snails were far lower than Fig. 3.3 suggests, as the smaller snails were especially sought to give a wide variation of size in the regression. Most of this generation at the time would be a subterranean habitat.

In the population and biomass study, population size reached the highest recorded level in the lowest rainfall year for 4 years (1976-77, 68.6mm). This is probably due to a lag effect. The population increase which was first detectable in autumn 1976 was a result of an influx of the generation begun in the rainfall year 1975-76. The extremely high 497mm in 1975-76 provided conditions extremely favorable for the production, development and survival of the snails which embody the 1976-77 population and biomass increase.

The more rapid increase in population and biomass in Areas 5 and 1-3 compared to Area 6 can be best explained by land usage. The snail population in Area 6, which was the highest in 1975-76, has been seriously hampered by continuous heavy grazing conducted in Area 6. Livestock compete with snails for green annuals and even eat some snails attached to foliage on which they are feeding. Thus with the extra source of mortality and less available food to aid survival, the recruitment rate has been less and the mortality rate more in Area 6 than in Areas 5 and 1-3. Areas 5 and 1-3 are both non-grazed and showed snail population growth in 1976-77 such that the population in Area 5 now exceeds that in Area 6 and the population in Area 1-3 has increased ten-fold since early 1976.

It is anticipated that few snails, adult or immature, will survive the 1977 summer. Conditions have not been good for the development and survival of the young snails. The 1976 generation was able to survive autumn and winter in the colder weather but spring has already produced a rapid population decline (Figs. 3.4, 3.5, 3.6). Summer mortalities have been high from both dessication and predation and will continue to diminish the snail population until the first heavy rainfall in September or October.

The snail size-structure study and biomass results show that maximum size increases take place in autumn, winter and early spring. Hence the maximum consumption of vegetation and maximum energy flow through the snails would take place in these seasons also. The snail population present in the 1976-77 season exhibits the highest biomass in the habitat of any single animal species. Thus their impact on the ecosystem must be correspondingly important. Little work has been done on the trophic behavior of snails. Snails evidently feed only in the high-humidity periods during the night and on days of precipitation, or when the soil surface is moist. At these times the snails forage on green annual plants and on green parts of some perennials. In seasonal and daily times of high temperature they seek shelter in the foliage on stems of woody perennials. Hopefully, some work on snail diet and ingestion rates can be conducted in autumn 1977.

Population and Biomass Estimates for Important Species not Effectively Sampled in Cage and Sweep Samples

Two other important categories of species, apart from ants and beetles, are not effectively sampled by cage or sweep samples:

(1) Transient species whose presence or peaks in population do not coincide with cage or sweep samples. These can appear in such numbers that their biomass is large compared to other arthropod species. More frequent samples than the seasonal cage and sweep samples are required to estimate these species' biomass.

(2) Species of very large body size which are not very common are seldom sampled in cage or sweep samples. However, their body size makes them important in biomass. Thus a larger sample area is required to detect them.

Method.-- At weekly intervals starting in March 1976, a 5 x 320 transect, between the meteorological station and the research site boundary fence, was carefully searched. Numbers of all large or numerous invertebrate species were recorded. Numbers and biomass per hectare were calculated for each species.

Results: In contrast to the large numbers and biomass of transient species found in spring and summer 1976 (Progress Report No. 5), numbers and biomass sampled in the transect in autumn 1976, winter 1976-77 and spring 1977 were very low (Table 3.18). Many species, very common in spring 1976 did not reappear in spring 1977 (792 Meloid bettle, 763 Lepidoptera larva and 917 spider). Others were present in reduced numbers (1631 Cocinellid beetle).

The large-bodied Orthopterans maintained population numbers and biomass in 1977 similar to those of 1976.

The failure of the transient species to appear in large numbers in 1977 was probably directly or indirectly due to the low precipitation in the 1976-77 rainfall season (68.6mm), compared to the 497mm recorded in 1975-76 and the consequent failure of the annual vegetation in spring 1977.

Table 3.18

Estimates of Number and Biomass per Hectare for Species Samples in Weekly Transects, 1976-77

	Sedentary Larva (Cat. No. 893)		Large Orthopteran (Cat. No. 830)		Small Orthopteran (Cat. No. 908)		Cocinelid Beetle (Cat. No. 1556)		Circullionid Beetle (Cat. No. 1631)	
Date	No/ha	Biomass Gm/ha	No/ha	Biomass Gm/ha	No/ha	Biomass Gm/ha	No/ha	Biomass Gm/ha	No/ha	Biomass Gm/ha
8/24/76	106.25	1.81	6.25	21.99	6.25	2.52			12.5	0.65
9/1/76	37.5	0.64	31.25	109.95	62.5	25.19				
9/11/76	56.25	0.96			6.25	2.52			18.75	0.97
10/22/76	18.75	0.32							56.25	2.92
10/28/76	93.75	1.59							18.75	0.97
11/5/76	81.25	1.38							18.75	0.97
11/10/76	62.5	1.06							25.0	1.3
11/19/76	143.75	2.44							12.5	0.65
11/26/76	87.5	1.49							6.25	0.32
12/4/76	87.5	1.49							12.5	0.65
12/15/76	68.75	1.17								
12/20/76	31.25	0.53							12.5	0.65
12/27/76	31.25	0.53							12.5	0.65
1/13/77	81.25	1.38								
1/18/77	81.25	1.38								
1/26/77	62.5	1.06								
1/31/77	37.5	0.64					31.25	0.17		
2/8/77	37.5	0.64								
2/14/77	68.75	1.17								
2/21/77	37.5	0.64								
3/1/77	31.25	0.53	6.25	21.99						
3/7/77	75.0	1.27	6.25	21.99						
3/15/77	18.75	0.32								
3/21/77	37.5	0.64	25.0	87.95						
3/30/77	50.0	0.85	6.25	21.99						
4/4/77	56.25	0.96	43.75	153.91						
4/14/77	43.75	0.74			18.75	7.56				
4/18/77	25.0	0.42	12.5	43.98	12.5	5.04	6.25	0.03		
4/26/77	31.25	0.53	12.5	43.98	6.25	2.52				
5/2/77	56.25	0.96					6.25	0.03		
5/9/77	43.75	0.74			12.5	5.04				
5/16/77	31.25	0.53								
5/22/77	100.0	1.7	6.25	21.99						

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In this and all subsequent reports on the native fauna in this volume, we wish to acknowledge the assistance of the following individuals. We are indebted to Amor Ferdjani, who has assisted in the field and laboratory with all investigations conducted by the Fauna Study Team. We are indebted to Carolyn Muir for drawing all diagrams, proof reading, and typing for the Fauna Report. She has assisted in the field with most studies and was responsible for all field work conducted with the snails.

CHAPTER 4
WILD VERTEBRATE POPULATION AND BIOMASS

by J.R. Muir and H. Heatwole

Population and Biomass of the Lizard Acanthodactylus Inornatus

The lizard *Acanthodactylus inornatus* was formerly recorded as *Acanthodactylus pardalus* in Progress Reports No. 3, 4 and 5. The species has now been determined as *Acanthodactylus inornatus* by Dr. P. Clanc of the University of Tunis, Tunisia.

Method.-- The method used in 1976 was identical to that described in the 1975 Progress Report (No. 4) and will only be briefly described here. Transect counts of active *A. inornatus* were conducted each season over a 24 hr period, at 2 hr intervals. The transect was 5 x 320 m between the meteorological station and the boundary fence, at the Dar ez Zaoui Research Site. Numbers of active *A. inornatus* per ha were estimated from the highest value recorded during each 24 hr transect study. Biomass was estimated per ha using 1973 summer *A. inornatus* dry-weight data. A correction was applied to biomass results based on snout-to-vent-length data, to calculate biomass for seasons other than summer, thus allowing for growth rate and size classes.

Snout-to-vent-length records were taken during stomach-content studies in 1974, 1975, and 1976, and were used to examine the size structure of the *A. inornatus* population in different sample seasons. This study was terminated in winter 1976-77 and hence only the results for autumn and winter 1976-77 are available in this report.

Results.-- The highest biomass of active *A. inornatus* per ha was recorded in spring 1977. This far exceeded that obtained in autumn and winter (Table 4.1). There was no significant difference (at .05 level) between snout-to-vent length of *A. inornatus* taken in autumn and winter. The mean for winter was lower than that for autumn (Fig. 4.1) which is the reverse of the normal trend, but the difference may be assumed to be due to random factors in sampling (Progress Reports No. 4,5).

Bird Population and Biomass Estimation

Method.-- As in 1976, a bird census was conducted once a month on the Dar ez Zaoui study site. Two or more investigators, about 50 m apart, made a line search sweeping back and forth across the site. No area was covered twice and each investigator had a specific area to search. Sweeps gradually progressed from one end of the validation

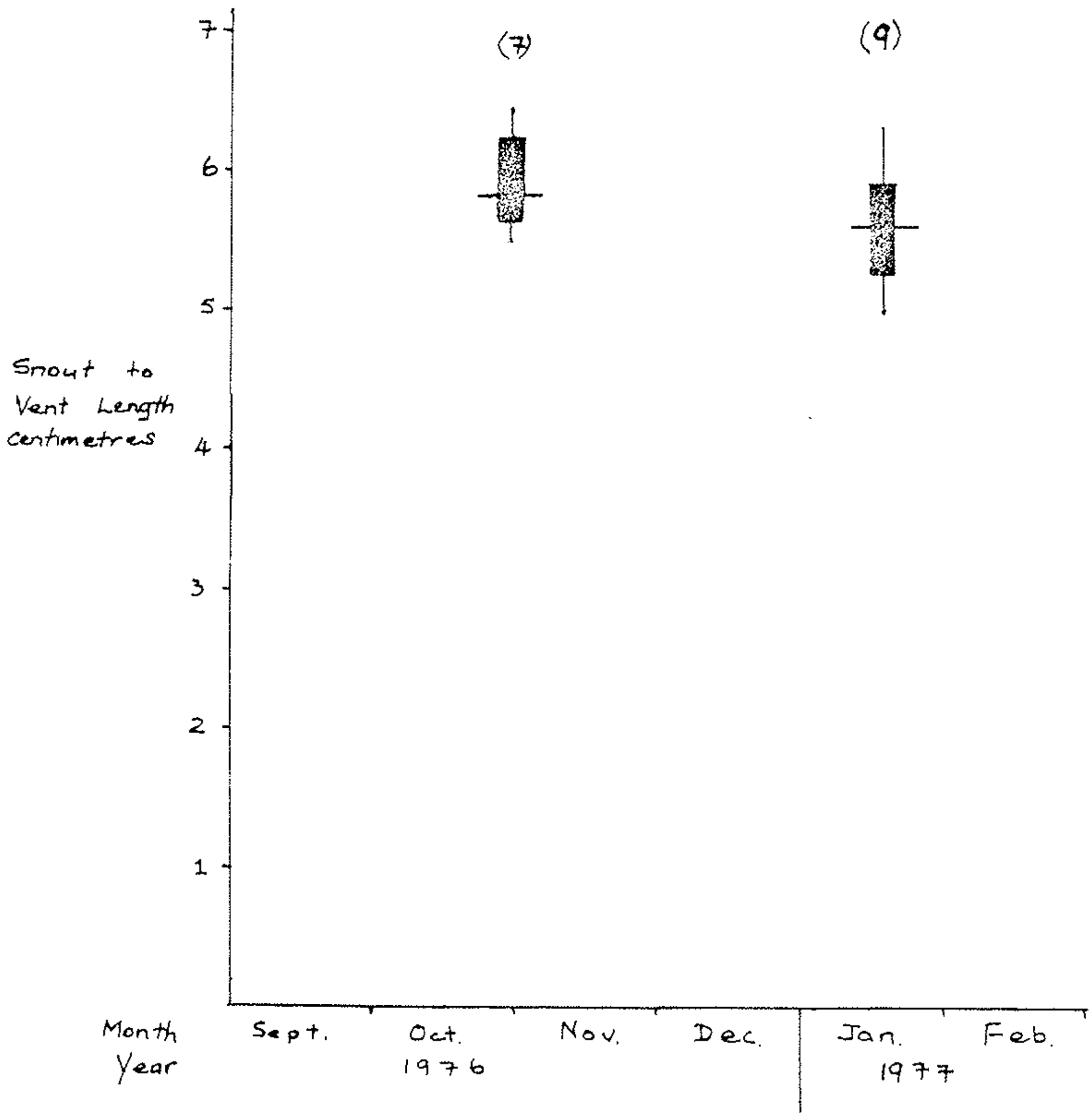


Figure 4.1. Snout-to-vent lengths for Acanthodactylus inornatus showing the mean, two standard errors of the mean and range for samples taken in autumn 1976 and winter 1976-77. Sample sizes are indicated in parentheses.

Table 4.1

Seasonal Numbers and Biomass of *Acanthodactylus inornatus* in Transect Samples Between Autumn 1976 and Spring 1977

Season	No/ha	Biomass G/ha	Corrected Biomass G/ha
Autumn 1976	18.8	25.2	18.5
Winter 1976-77	12.5	16.8	12.6
Spring 1977	43.8	58.8	50.5

site to the other. All sighted birds within the sweep limits were counted. Birds flying across the sweep area were only counted if their flight direction was from the unswept to swept area. Number of individuals per ha was calculated for each species and, where possible, biomass per results from the 1976 Report are included to give a year's continuous record (Table 4.2).

Results.-- The following bird species were recorded at the research site between April 1976 and April 1977. Expected seasonal patterns in the research site area are given for each bird species (Heinzel, Fitter and Parslow; 1973 *Oiseaux d'Europe*). Common names assigned by the investigators are also given:

Callendrella rufescens	Finch	Present year round
Alauda arvensis	Lark	Present year round
Lanius excubitor	Shrike (black head)	Present year round
Lanius senator	Shrike (brown head)	Present spring and summer
Motaçilla alba	Wagtail	Present in winter
Athene noctua	Owl	Present year round
Streptopelia turtur	Dove	Present in spring and summer
Oenanthe oenanthe	Traquet (grey head)	Autumn, spring while migrating
Oenanthe deserti	Traquet (sandy head)	Present year round
Hirundo rupestris	Swallow	Present winter
Sylvia conspicillata	Fauvette	Present year round
Phoenicurus ochruros	Orange tail	Present in winter
Falco tinunculus	Falcon	Present year round

Other birds seen in the area but not recorded during censuses were:

Monticola solitarius	Merlebleu	Present year round
Merops apiaster	Guepier	Autumn, spring while migrating
Turdoides fulvus	Craterope	Present year round

Table 4.2

Bird Numbers and Biomass per Hectare at the Dar ez Zaoui Research Site Between April 1976 and April 1977

Species		Number and Biomass per Ha by Date												
		4/2/76	4/19/76	5/13/76	6/7/76	7/23/76	8/9/76	9/14/76	10/28/76	11/27/76	12/20/76	2/7/77	2/21/77	4/4/77
Callendrella rufuscens	No/ha	2.1	2.1	2.0	1.7	0.7	1.3	0.7	1.6	1.2	1.8	2.0	0.9	1.8
	Gm/ha	16.9	16.9	16.2	13.5	5.5	10.4	5.8	12.5	9.8	14.3	16.1	7.4	14.5
Alauda arvencis	No/ha	0.3	0.2	0.3	0.6	0.4	0.4	0.4	0.9	0.5	1.1	1.0	1.2	0.9
	Gm/ha	3.9	3.1	3.7	9.0	5.6	5.1	5.9	12.4	6.7	15.4	14.0	17.1	13.2
Lanius excubitor	No/ha	0.02	0.02			0.02	0.04	0.1	0.1	0.04	0.04	0.04		0.04
	Gm/ha	0.5	0.5			0.5	0.9	1.8	1.4	0.9	0.9	0.9		0.9
Lanius senator	No/ha	0.02	0.02											0.1
Motacilla alba	No/ha	0.02	0.02							0.02	0.02			
	Gm/ha	0.2	0.2							0.2	0.2			
Athene noctua	No/ha	0.02	0.02	0.02										
	Gm/ha	1.0	1.0	1.0										
Streptopelia turtus	No/ha	0.02							0.02	0.04				
Oenanthe oenanthe	No/ha	0.1	0.1											0.1
Oenanthe deserti	No/ha								0.02					0.1
Hirundo rupestris	No/ha		0.24											0.04
Sylvia conspicillata	No/ha									0.02	0.1	0.02	0.04	
Phoenicurus ochrurus	No/ha									0.1				
Falco tinunculus	No/ha			0.02										
Unidentified	No/ha		0.1											
Total	No/ha	2.6	2.8	2.3	2.3	1.1	1.7	1.2	2.5	1.9	3.0	3.1	2.2	3.0
	Gm/ha	22.4	21.5	20.8	22.5	11.5	16.4	13.5	26.2	17.6	30.8	31.0	24.5	28.6

The most common birds present throughout the year were the allouettes, Callendrella rufescens and Alauda arvensis, and these comprise most of the bird biomass recorded at Dar ez Zaoui (Table 4.2). Both nest on the research site in nests hidden in perennial shrubs close to the ground. Eggs are laid in early spring and fledglings appear in late spring and early summer. Alauda arvencis has always been noted to feed singly, or in pairs or small, loosely bound family groups. Callendrella feed in cohesive small groups in winter and early spring, but form large flocks in late spring, summer, and autumn. The predaceous shrike, Lanius excubitor, was recorded throughout most of the year.

No other species were recorded in summer. Some occurred in certain seasons and others only briefly while migrating through the area. Four other species do occur in the region throughout the year but were recorded only sporadically in censuses. The Dar ez Zaoui study site is probably a marginal habitat for the fauvette, Sylvia conspicillata, and the traquet, Oenanthe deserti, and would only be a small part of the home ranges of the large predators, Falco tinunculus and Athene noctua.

The absence of migratory and seasonal species in summer and the decline in records of the allouettes gives summer a low bird population and biomass compared with other seasons (Table 4.2).

Rodent Population Study

Since 1974, a gradual build up of the incidence of rodent warrens has been noted on the research site. Thus an attempt has been made, starting in spring 1976, to measure rodent population and to assess their impact on the ecosystem. A year's study was completed in winter 1976-77. Though results for spring and summer have already been submitted in the 1976 Report, they will be included in this report for comparison with subsequent seasons.

Estimation of rodent numbers and biomass.--

Methods: The rodent population in the destructive sampling zone of the Dar ez Zaoui research site has been sampled four times, once in each season, by capture-recapture live trapping. The samples were taken from 17-24 May 1976 in spring, from 20-28 July in summer, from 25 November to 5 December 1976 in autumn, and from 10-19 January 1977 in winter.

For all samples a grid of live traps was set up at 20 m intervals, 14 traps wide and 14 traps deep. A total of 196 traps covered an area of 6.76 ha. Traps were baited in the late afternoon and checked at sunrise the following day in spring and summer. In autumn and winter traps were also checked at night to reduce mortalities. Bait was peanut butter and dried fish in spring, and peanut butter and dates (chopped) in summer, autumn and winter.

Captured animals were identified to species or genera, weighed, and marked with unique earmarking to allow identification of individuals. We are grateful for access to the animal collection made by T.C. and P.J. Vaughan in 1973-74, and for the use of their key to help identify rodent species.

Numbers per ha and live and dry wight per ha were calculated for trapped animals using an adjusted trapping area to allow for extension of home ranges beyond the area trapped. Estimates of trappable animals were made by the Schnabel method and by regression of number of new captures by numbers marked at large. To include untrappable animals in estimations in summer, autumn and winter, all animals were marked with large India ink and/or Mercurochrome blobs. After the last trapping night, observations were conducted to determine the ratio or marked to unmarked animals so that animals/ha and biomass could be calculated.

Results: The following species were captured during the four samples:

Meriones shawii	Shaws jird
Gerbillus henleyi	Pigmy naked-footed gerbil
Gerbillus aureus	Setzer's hairy-footed gerbil
Gerbillus pyramidus	Greater Egyptian hairy-footed gerbil
Gerbillus gerbillus	Lesser Egyptian hairy-footed gerbil
Gerbillus amoenus	Southern naked-footed gerbil

Though not captured, a jerboa, Jaculus jaculus was observed active near the validation site and found dead on the roadside. The Libyan jird, Meriones libycus has been captured outside the study site. Captures were very low in both May and July. The most common species captured in both seasons was Meriones shawii which was the only species captured in July. One each of G. gerbillus, G. pyramidus, and G. amoenus were taken in May (Table 4.3). In November and January captures were much higher with G. henleyi, the most common species, followed by Meriones shawii and G. aureus in both seasons (Table 4.3, Fig. 4.2).

In spring and summer most animals were in reproductive condition (pregnancy and swollen genitalia). No animals were noted in reproductive condition in late autumn or winter, and it was very difficult even to sex animals in these seasons.

Population and biomass figures given for spring cannot be effectively compared with those for the other seasons as they represent total captures only and not an estimate to total population. Captures were too few to apply capture-recapture or regression methods and the observation study of the ratio of marked to non-marked animals was not initiated until summer.

Estimates of Meriones shawii population size and biomass for summer, autumn and winter were similar. Though summer had the lowest estimate

Table 4.3

Estimated Numbers and Biomass of Rodents in the Destructive Sampling Zone, Spring 1976 to Winter 1976-77

Species		Corrected Sample Area	Spring 1976 No. Caught	Spring 1976 No/ha	Spring 1976 Live Wt. Gm/ha	Spring 1976 Dry Wt. Gm/ha	Summer 1976 No. Caught	Summer 1976 No/ha	Summer 1976 Live Wt. Gm/ha	Summer 1976 Dry Wt. Gm/ha	Autumn 1976 No. Caught	Autumn 1976 No/ha	Autumn 1976 Live Wt. Gm/ha	Autumn 1976 Dry Wt. Gm/ha	Winter 1976-77 No. Caught	Winter 1976-77 No/ha	Winter 1976-77 Live Wt. Gm/ha	Winter 1976-77 Dry Wt. Gm/ha
Meriones shawii[1]	A		3				5				11				10			
	Im1	8.51 Ha	0	.5	33.7	10.5	1	3.2	307.0	84.3	6	4.2	275.4	76.4	8	3.7	270.3	76.5
	Im2		0				0				11				4			
	J		1				0				0				0			
Gerbillus henleyi		7.69 Ha									48	9.3	106.7	22.5	42	6.5	74.9	15.8
Gerbillus aureus		8.04 Ha									6	.8	26.9	5.7	4	.5	15.8	3.8
Gerbillus gerbillus		7.69 Ha	1	.1	2.4													
G. pyramidum		7.69 Ha	1	.1	7.9													
G. amoenus		7.69	1	.1	2.7													

Estimation Methods for Total Rodent Numbers in Sample Area

	No Estimation	Total Count Only	Observation Method: No. Marked Animals	Observation Method: Total Observed	Observation Method: Marked Observed	Observation Method: Estimate	Capture Recapture Estimate	Regression Estimate	Mean	Caputre Recapture Estimate	Regression Estimate	Mean
Meriones shawii		4	6	9	2	27	33.2	38.7	35.9	33.6	28.8	31.2
Gerbillus henleyi							83.2	59.6	71.4	54.3	45.3	49.8
Gerbillus aureus							Sample too Small	Total Captured	6	Sample too Small	Total Captured	4
Gerbillus gerbillus		1										
Gerbillus pyramidum		1										
Gerbillus amoenus		1										

[1] Meriones sizes A = Adult Im1 = large immature Im2 = small immature J = Very young

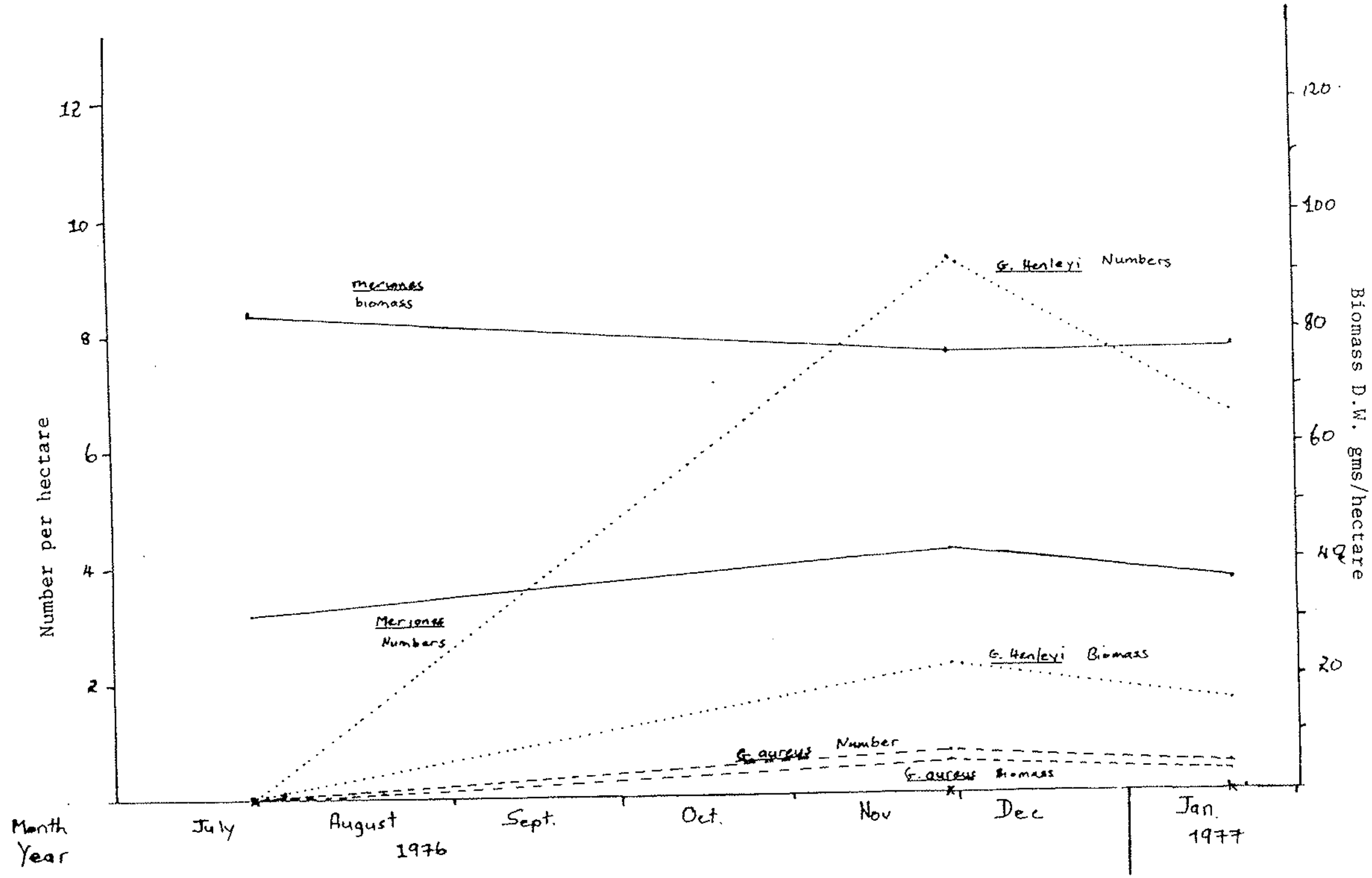


Figure 4.2. Rodent population density and biomass per hectare, estimated in summer 1976, autumn 1976 and winter 1976-77 in the destructive sampling zone, Dar ez Zaoui Study Site.

of Meriones population, its live-weight-per-ha and dry-weight-per-ha estimates were higher than those in the other two seasons due to the high proportion of adults in the captured population in summer. Similarly, in autumn, when the Meriones population estimate was higher than in winter, the high proportion of young and immatures captured gave a biomass estimate similar to that of winter (Table 4.3, Fig. 4.2). Gerbillus henleyi and Gerbillus aureus, which were caught only in autumn and winter, showed decreasing population and biomass between these two seasons (Table 4.3 and Fig. 4.2). Gerbillus henleyi, though the most common species captured in winter and autumn, showed lower biomass estimates than Meriones due to its very small body size (Table 4.3, Fig. 4.2).

Of the four Meriones caught in spring two were recaptured in summer and one was recaptured in autumn and winter. Of the additional Meriones taken, in summer, none were recaptured in winter. Of the 36 G. henleyi taken in autumn, 18 were recaptured in winter. Only one Gerbillus aureus was taken in both autumn and winter samples.

Discussion: The main problem with assessing the population and biomass of the rodent species at the Dar ez Zaoui research site has been the lack of uniformity in methods of population estimation applied at each sample time. This has been due to a number of factors usually related to the time of year of sampling. For instance, in the warm May and July samples when very few animals were caught, the Tenebrionid beetle Pimelia obsoleta, and the harvesting and scavenging ants (Cat. Nos. 741, 748, and 601, 684 respectively) were active at night. Pimelia frequently set off traps and the ants invaded over 90% of the traps for the whole night trapping period carrying off many baits. The influence of ants in particular, was probably quite high as the rodents caught were consistently taken in traps not visited by ants. Thus rodent captures were so low that capture-recapture and regression methods could not be applied.

For the July sample, a mark-observation method was successful in estimating the ratio of trapped to untrapped animals and hence population and biomass. Unfortunately, this method was unsuccessful in autumn and winter samples, in both night and day-time attempts at observation there were few sightings of active rodents.

In the cooler autumn and winter samples, Pimelia and most of the ant species were active in the day-time so that traps were generally undisturbed. Thus captures were high and capture-recapture and regression estimation methods were applied. However this did not allow for trappable animals and it is probable that estimates of both population and biomass for autumn and winter are conservative. Another problem in autumn and winter were attacks on trapped animals by predators. Toward the end of each sample, tracks of feral cat, fox and domestic dog were noted along the trap lines. Many traps were overturned and animals released.

At least one G. henleyi was killed by a predator and it is thought that some Meriones were also taken as several were not recaptured after the traps in which they were normally caught were found overturned by a predator.

In spite of running the traps at midnight, there was a large number of G. henleyi mortalities in the autumn and winter samples. This is thought to be due to a combination of exposure and shock as all deaths were "new" unmarked animals. Recaptures were always living.

Thus, with problems of estimation, interference from other species, mortality due to predation and exposure, the rodent study cannot give a confident indication of trends in population and biomass over all four seasons. Though differences in trapping probabilities and failure of observations prevent confident comparison of spring and summer samples with those of autumn and winter, the autumn and winter samples may be compared. It appears that for all three species caught, Meriones, G. henleyi and G. aureus, the populations reached a peak in autumn and declined in winter (Fig. 4.2). It is thought that Meriones has built up to the autumn peak from lower numbers in spring and summer (see Warren Study), and from its first appearance on the site in 1975. The situation with G. henleyi is less clear. None were caught in spring or summer but then a peak of population was estimated for autumn. The failure to record G. henleyi in spring and summer might be due to trap shyness in warm weather or their sudden multiplication or influx between the summer and autumn samples. The apparent decrease in G. henleyi population between autumn and winter must be treated with caution as the decrease could have been generated by the autumn sample where there was a mortality of 12 G. henleyi.

In comparing results with those obtained by Vaughan in 1973, it may be noted that there is a difference in the dominant species. Vaughan records G. gerbillus dominant with 446.2 gms live weight per ha in April, and 95.7 gms live weight ha in November. Meriones was recorded as the second most important species with 78.9 gms live weight per ha in April, and 39.5 gms live weight per ha in November. G. henleyi had the lowest biomass of 12.1 gms live weight per hectare in April, and 6.9 gms live weight per ha in November. Though no comparison can be made with the 1973 April sample, the November 1976 sample gives higher live weight values per ha for both Meriones (275.4 gms) and G. henleyi (106.7 gms) than recorded for any species in November 1973. In terms of dry weight biomass, Meriones shawii and Gerbillus henleyi were, at the research site.

Thus, a G. gerbillus-dominated rodent fauna in 1973 has changed to a Meriones-and G. henleyi-dominated rodent fauna in 1976-77. It is not understood if the change has been in response to changing environmental factors, or if internal population cycles have played an important role.

In 1977, one sample only will be conducted in autumn and will be compared with the autumn 1976 sample. In other seasons the rodent study has been continued only with the rodent warren mapping.

Rodent warren study.-- One of the most obvious signs of rodent presence in their warrens. Meriones warrens are built mainly in the nebka and loose soil surface areas of the research site and consist of a number of surface holes about 50-75mm in diameter, leading to interconnecting tunnels. Few holes or warrens are dug in the hard-crusted soil surface characteristic of Area 5 and some inter-nebka spaces. The warrens have a loosening effect on the nebkas, as soil and annual plants around entrance holes are dug up. Under dry conditions this could create a wind-erosion problem in the very areas where it is important to maintain cohesive soil.

Gerbillus henleyi construct warrens with smaller entrance holes (< 40mm dia.) and fewer holes per warren. These may be found in nebkas or in the hard-crusted soil surface areas. G. aureus constructs warrens similar to those of Meriones but usually smaller. They may be commonly found in nebkas around large Rhetama plants. The warrens, particularly those of Meriones, provide a refuge for certain animals and the distribition and numbers of warrens and holes influence populations of these animals.

To investigate the influence of warrens on the soil surface and on dependent animal species, the extent and number of warrens and holes was examined in the destructive sampling zone each season starting in spring 1976.

Methods: Over the entire destructive sampling zone, which includes the area sampled in the live-trapping study, all rodent warrens were counted and mapped each season on the following dates:

Spring, 4/14-15/76, (Fig. 4.3)
Summer, 7/20-25/76, (Fig. 4.4)
Autumn, 11/28 / 76, (Fig. 4.5)
Winter, 1/27/76-2/16/77, (Fig. 4.6)
Spring, 5/3-6/77 (Fig. 4.7)

Numbers of open entrance holes to each warren were also counted and the total surface area covered by warrens was calculated. The maps were examined for any distribution pattern of warrens in relation to area type and land usuage, and compared to assess any differences in warren distribution and density between the different seasons. Maps show only Meriones and G. aureus warrens. G. henleyi warrens were difficult to define due to a wide scatter of holes. Thus no attempt was made to calculate area covered by G. henleyi warrens or to count the number of warrens (Table 4.4).

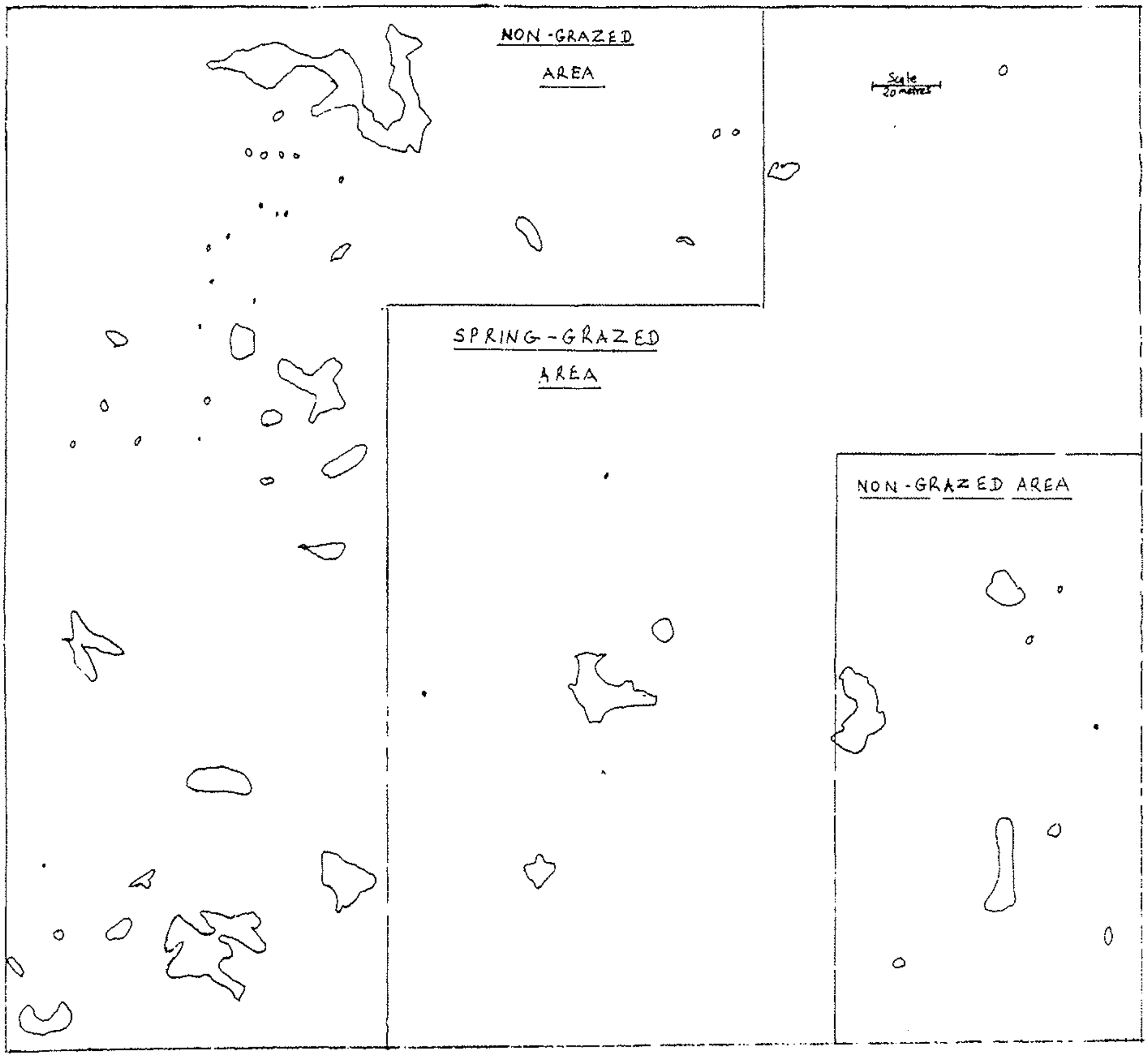


Figure 4.3. Map of the destructive sampling zone, Dar ez Zaoui, showing distribution of, and area covered by rodent warrens on 4/14,15/76 (G. henleyi and very small warrens are not shown).

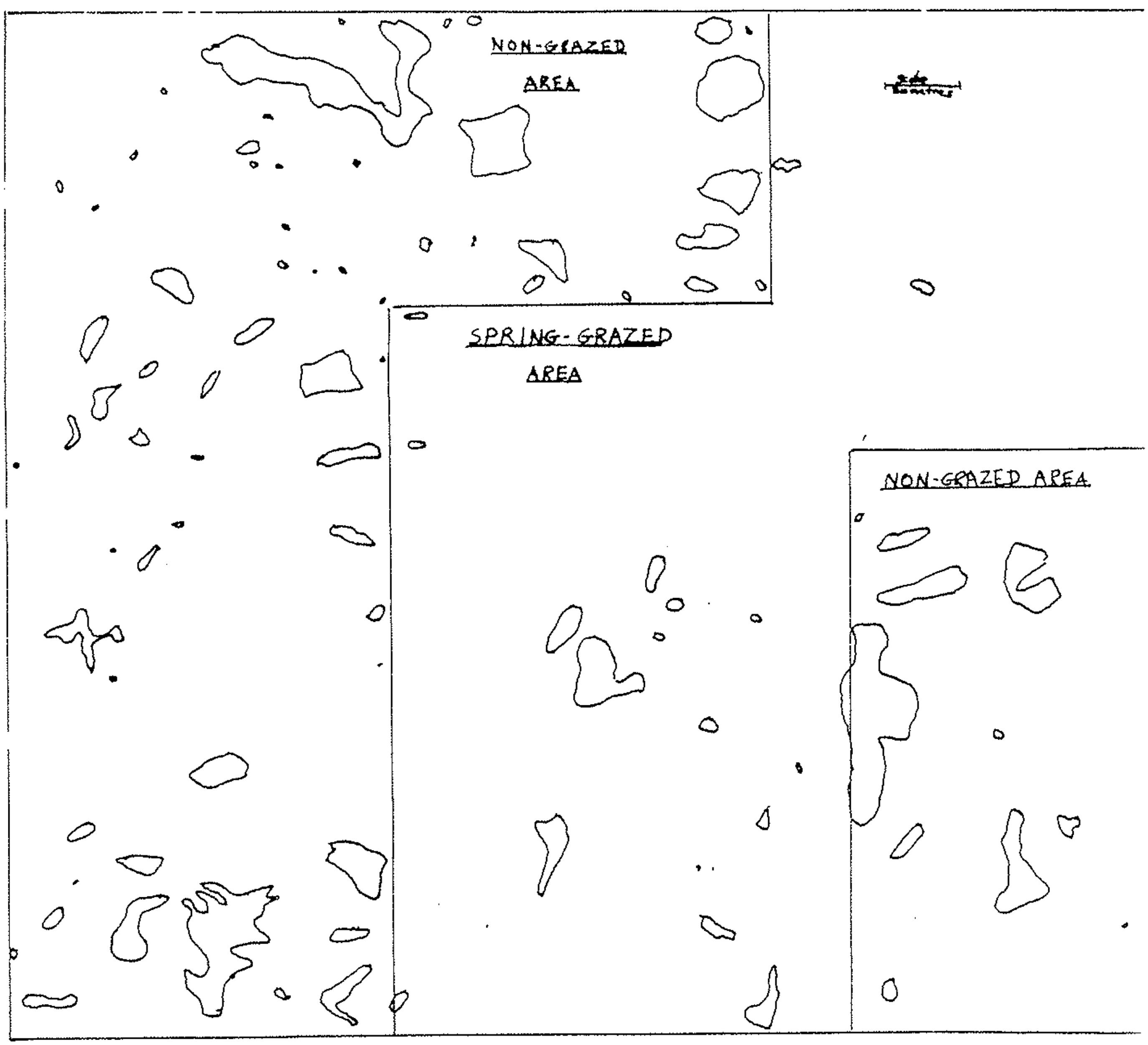


Figure 4.4. Map of the destructive sampling zone, Dar ez Zaoui, showing distribution of, and area covered by rodent warrens on 7/20-25/76 (G. henleyi and very small warrens are not shown).

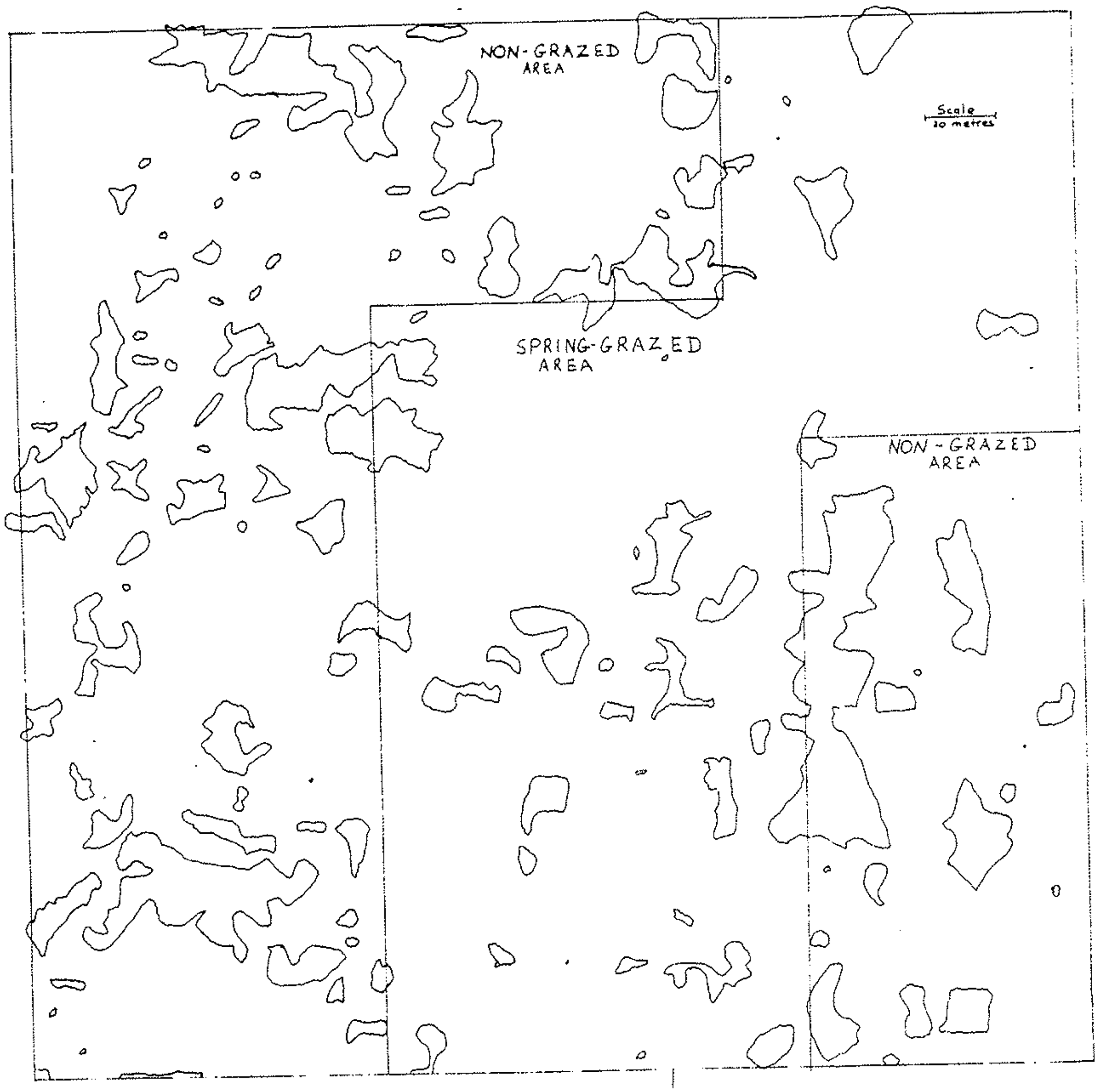


Figure 4.5. Map of the destructive sampling zone, Dar ez Zaoui, showing distribution of, and area covered by rodent warrens on 11/28/76-12/5/76 (G. henleyi and very small warrens are not shown).

Table 4.4

Numbers of Rodent Warrens and Entrance Holes per Hectare, and Percentage of Surface Areas Covered by Warrens, Spring 1976 to Spring 1977

		Warren Distribution by Grazing Treatment					
		Spring Pasture (3.76 ha)			Non-grazed (5.23 ha)		
Season	Date	% Area Covered	Holes/ha	Warrens/ha	% Area Covered	Holes/ha	Warrens/ha
Meriones shawii and G. aurens							
Spring 1976	4/14/76 to 4/15/76	.9	34.6	2.8	3.8	243.8	8.9
Summer 1976	7/20/76 to 7/25/76	1.7	81.6	5.0	8.9	417.6	18.4
Autumn 1976	11/28/76 to 12/5/76	7.2	447.3	9.0	19.2	880.0	15.3
Winter 1976-77	1/27/77 to 2/16/77	9.5	577.9	10.9	19.0	976.1	14.5
Spring 1977	5/3/77 to 5/6/77	10.7	582.2	11.7	17.6	907.1	14.9
G. Henleyi							
Autumn 1976	11/28/76 to 12/5/76		63.6			123.3	
Winter 1976-77	1/27/77 to 2/10/77		64.4			149.4	
Spring 1977	5/3/77 to 5/6/77		62.8			112.2	

Results: Two trends stand out in the maps representing seasonal rodent warren distribution. There was a sharp increase in the area covered by Meriones and G. aureus warrens from spring through summer to autumn (Figs. 4.3, 4.4 and 4.5). Between April and November, the non-grazed areas showed an increase of from 3.8% to 19.2% area covered, and the grazed area from .95% to 7.2%. This increase was accompanied by a similar increase in numbers of entrance holes per ha (Table 4.4, Fig. 4.8). Warren numbers did not increase to the same degree due to the merging of adjacent warrens. In fact there was a decrease in warren number in the non-grazed area between summer and autumn even though there was an increase in holes and area covered (Table 4.4, Fig. 4.8). After November the area covered and hole number appeared to stabilize. In the spring-grazed area there was a relatively small increase from 7.2% to 10.7% area covered between November and May, and in the non-grazed area a slight decline from 19.2% to 17.6% (Table 4.4, Fig. 4.8). G. henleyi holes were noted in low numbers in summer but were not counted until November 1976. Since that time the hole number per ha has been relatively stable in both grazed and non-grazed areas (Table 4.4b).

The second trend was the difference between the spring-grazed and non-grazed areas in area covered and number of holes per ha (Figs. 4.3, 4.4, 4.5, 4.6, 4.7 and 4.8, Table 4.4). In the five seasonal samples the area covered by, and the number of entrance holes of, Meriones and G. aureus were considerably higher in the non-grazed area than in the spring-grazed area. Non-grazed records exceeded grazed records in spring and summer 1976 by a factor of 4 to 5. This was gradually reduced to a factor of less than 2 by spring 1977 (Table 4.4, Fig. 4.8). G. henleyi was also more numerous in entrance holes in the non-grazed area than in the spring-grazed area from November to May. Entrance hole number in the non-grazed area was about double that in the spring-grazed area (Table 4.4).

Discussion: The sharp increase in Meriones warren activity between spring 1976 and autumn 1976 might be a seasonal phenomenon but might also suggest that the population of Meriones was increasing. This is supported by population and biomass data (Table 4.3), particularly where population levelled off and decreased slightly between autumn and winter as was also noted in warren results (Table 4.4, Fig. 4.8 non-grazed area). Thus with the large increase in warren activity between spring 1976 and autumn 1976 and the continuity of near autumn levels through to spring 1977, Meriones is potentially an important agent of soil erosion, particularly since the 1976-77 precipitation has been well below average (68.6mm).

Differences in warren cover and entrance hole number between grazed and non-grazed areas suggest that there is a degree of competition between Meriones and livestock. Heavy grazing could reduce available food supplies for Meriones.

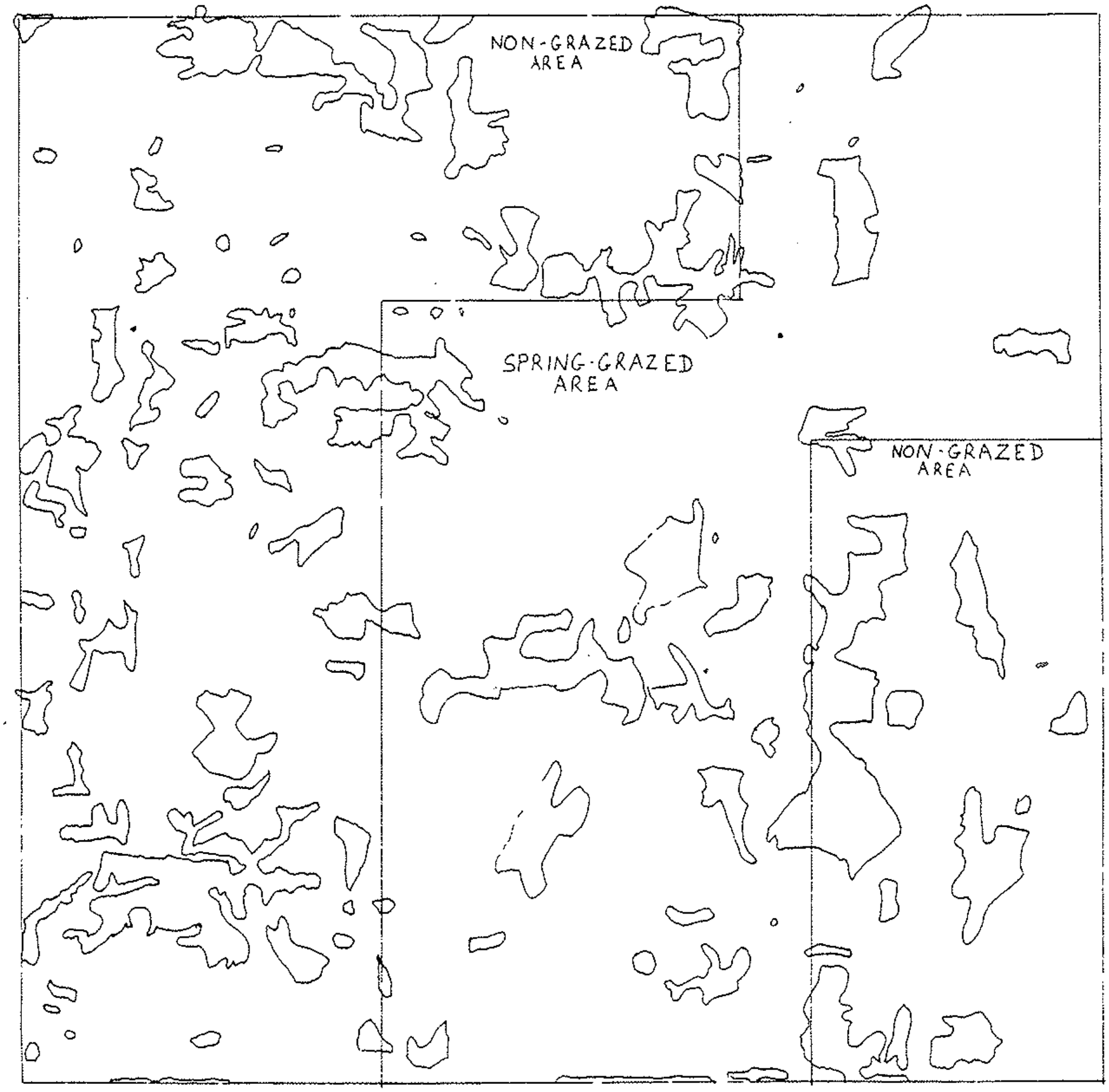


Figure 4.6. Map of the destructive sampling zone, Dar ez Zaoui, showing distribution of, and area covered by rodent warrens on 1/27/77-2/16/77 (G. henleyi and very small warrens are now shown).

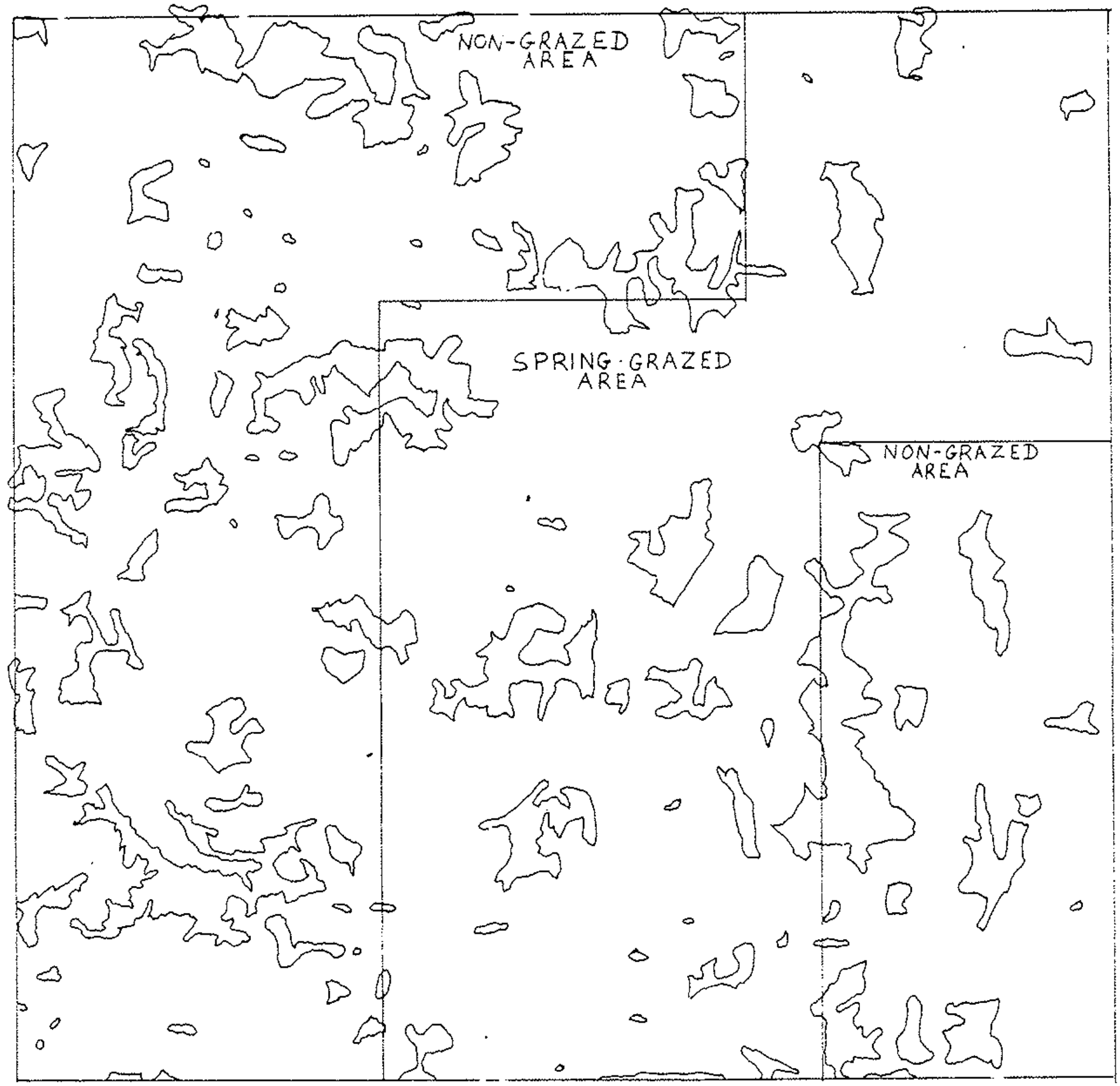


Figure 4.7. Map of the destructive sampling zone, Dar ez Zaoui, showing distribution of, and area covered by rodent warrens on 5/3-6/77 (G. henleyi and very small warrens are not shown).

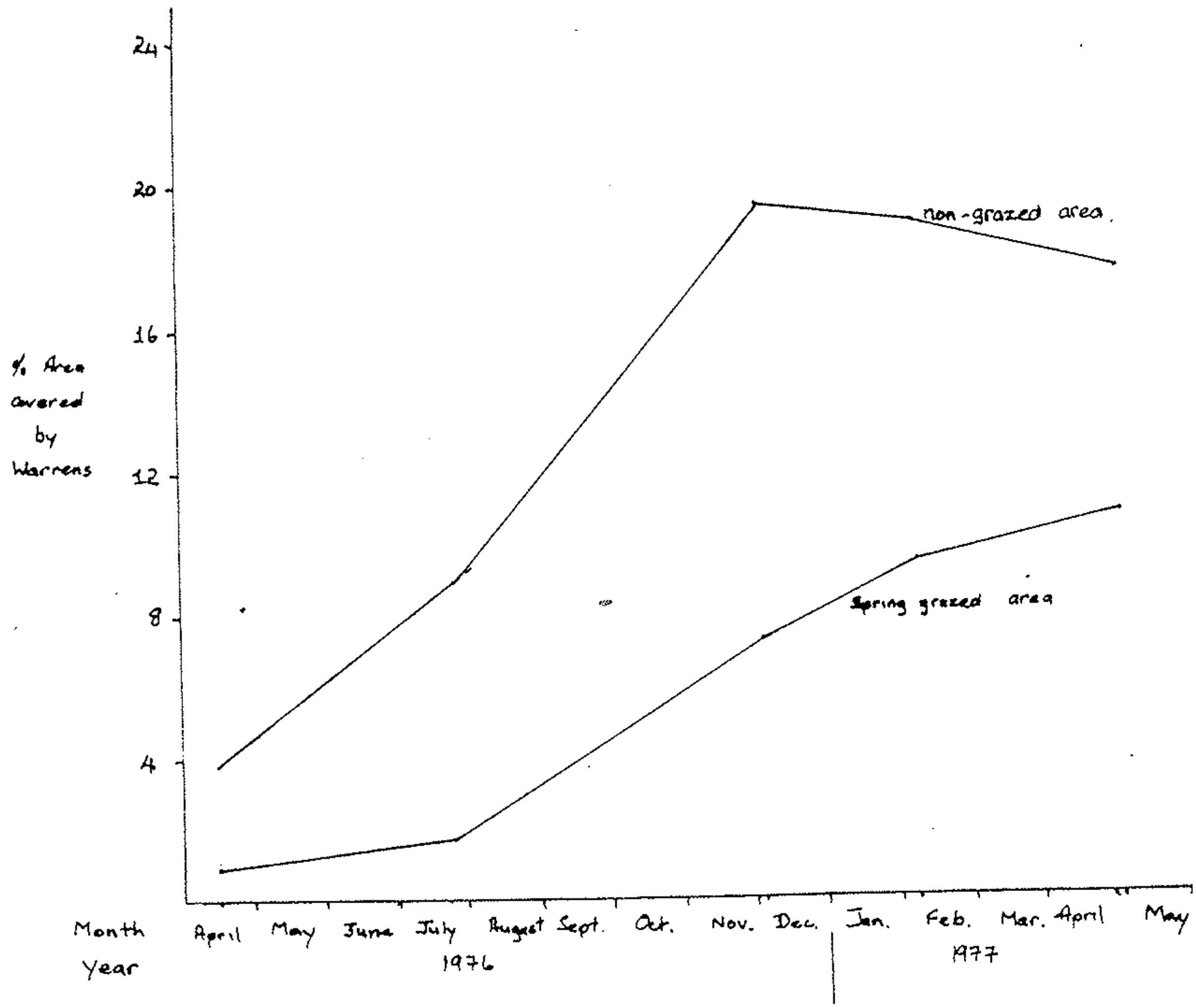


Figure 4.8. Percentage of area covered by Meriones and G. aureus warrens in non-grazed and spring-grazed Areas between April 1976 and May 1977 at the Dar ez Zaoui Study Site.

Interference by livestock with the warrens and holes by trampling could also suppress *Meriones* activity. The influence of livestock was confirmed during the period following spring grazing when plants were recovering. The warren activity in the grazed area in autumn, winter and spring 1976-77, once grazing had ceased, gained considerably on warren activity in the non-grazed area, (Fig. 4.8). The spring-grazed area has been rezoned for summer grazing in 1977 so that the effect of 1977 grazing on warren activity in the grazed zone has not yet been assessed.

CHAPTER 5

STOCKING RATES OF SHEEP AND GOATS

by D. Coleman Crocker-Bedford and
Kara-Lynn Crocker-Bedford

Introduction

The densities of the herbivores are among the most important parameters of energy flow through an ecosystem. Measurement of herbivore densities is essential for calculating on a per-unit-area basis the consumption of primary production and the amount of secondary production.

In the first section of this chapter we will analyze the numbers of sheep and goats per unit area and their population trends. We will theorize on the manner in which their numbers are set, and will briefly comment on how population changes by sheep and goats are likely to affect the range.

In the second section of this chapter, we will give a history of the recent use of each pasture controlled by the Tunisian PreSaharan Project. Such knowledge is essential for understanding the range trends occurring in each pasture.

Stocking Rates of Local Flocks

Methods. -- We supervised the censuses of several flocks located near the Tunisian PreSaharan Project study site. Seven censuses occurred from April 1976 until May 1977. Project personnel counted the animals in each flock rather than relying on verbal responses by the flock owners, except in May 1977. The surface area grazed by a flock during a year was reported by the flock owner. Such areas are not accurate because the flock owners themselves do not know exactly how much land they have, and for other reasons. Therefore, we deal with the absolute numbers of animals present whenever possible, rather than the numbers per unit area.

Results and discussion.-- Table 5.1 demonstrates that the people of Chaabania are loath to give up their animals until they absolutely must. By late December 1976 it was obvious that a poor rainfall year was in progress, and that all females which would reproduce either had given birth or were obviously pregnant. Our project therefore culled its weaker, nonreproducing individuals, but the neighbors did not. This was a favorable time to cull because no young were on the market; thus sale prices were good -- about 15 dinars per adult older than yearling.

By the end of February, the forage outlook was even bleaker than before. Since weaning was well under way, one had the opportunity to cull many old or sick animals whose young were weaned. Prices were now a moderate 10 dinars per adult older than yearling, because a few

Table 5.1

Stocking Rates of Adults (Animals Born by June 1976) Near the Tunisian PreSaharan Project During the Agricultural Year 1976-77

Flock	Hectares[a]	No. of Sheep, Goats and Total Stocking Rates by Date, Species and Sex																								
		29 September					16 December					17 February					13 April					11 May				
		Sheep		Goats		No./ha	Sheep		Goats		No./ha	Sheep		Goats		No./ha	Sheep		Goats		No./ha	Sheep		Goats		No./ha
		♂	♀	♂	♀		♂	♀	♂	♀		♂	♀	♂	♀		♂	♀	♂	♀		♂	♀	♂	♀	
A	90	3	27	6	24	.67	1	22	2	19	.49	1	19	2	17	.43	1	19	2	17	.43	1	19	2	17	.43
B	100	2	51	4	23	.80	2	44	1	21	.68	2	39	1	21	.63	2	36	1	23	.62	1	32	1	23	.57
C	175	4	25	4	21	.64	3	26	5	18	.60	3	26	5	18	.58	3	26	4	18	.57	3	23	4	18	.55
D		2	16	9	31		1	15	5	32		1	15	5	28		1	15	5	28		1	14	5	28	
E	200[b]	Not Present ----------					3	58	4	70	.67	3	58	4	65	.65	2	58	4	65	.64	2	58	4	65	.64
Total W/O E	365	11	119	23	99	.69	7	107	13	90	.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total W/E	565	Not Applica				------	10	165	17	160	.62	10	157	17	149	.59	9	154	16	151	.58	8	146	16	151	.57
Project on date	128	3	43	4	44	.73	3	40	4	42	.70	3	36	3	35	.60	3	31	3	33	.55	3	27	3	28	.48
Following date	128	3	41	4	44	.72	3	36	3	35	.60	3	31	3	33	.55	3	27	3	28	.48					

[a] These approximations of total pasture areas are similar to those used by Bedoian's (Table 13.6 Progress Report No. 4 and pers. comm.).

[b] This flock grazed 170 ha near the project site for 9 or 10 months annually. Therefore over 12 months it would have used about 200 ha $\approx$ 170 x 12/10.

[c] Following the reductions on these dates: 24 December, 25 February and 19 April.

lambs were marketed before March. Our project could have culled more animals in February, but did not wish to cause too great a divergence between its stocking rate and that of the neighbors.

In April the project decided it should no longer wait to sell until the neighbors culled. Thus more animals were sold, but the price was now only 7.5 dinars per adult older than yearling.

Between the April and May observations, the neighboring flocks finally began to decrease in size: 1 ram was sold and 8 ewes and 3 lambs sickened until they died or were slaughtered by their owners. No project animals sickened in the same period. We conjecture that the diseases were fatal because of poorer nutrition. During the May observation some of the flock owners began to admit that they would possibly lose many of their animals during the summer of 1977; however, they stated that they would not sell animals until they exhausted their supply of grain.

The neighbors did cull some old animals. Although a few does, but no ewes, were culled during summer 1976, many adults were culled during the autumn. Between the September and December observations adults decreased by 14 percent. About half of this decrease consisted of young adults born the previous agricultural year -- a continuation of the selling of lambs and kids. The other half consisted of old animals culled before it was known whether they would bear young and before the quality of the agricultural year was known. Thus, except for animals which were recently lambs and kids, the neighbors culled only old animals which they thought were likely to become sick, and these animals were culled when their market value was greatest. Seemingly, the amount of culling was not based upon the amount of forage available.

It therefore appears that the local people did not heed the fact that the rainfall occurring in 1976-77 would be inadequate to maintain their present flock sizes. Rather than culling some adults when the prices were good in December, January and February, they waited for the animals to sicken, thereby increasing the consumption of the already scarce forage.

This reluctance to reduce flock size seems further inappropriate because the ewe and doe population in 1976-77 was 5 percent larger than in 1975-76 (Table 5.2) and 20 percent larger than in 1974-75 (Table 5.3), and considering that forage production was much lower in 1976-77 than in the 2 earlier years. Furthermore, flock sizes had increased by 80 percent between 1972-73 and 1974-75 (cf. Bedoian in later chapter of this Progress Report). Thus more than twice as many sheep and goats were present in 1976-77 as 4 years earlier.

Hence, we theorize that the stocking strategy of the local people is to keep almost all animals unless they require money or meat, or until nutritional difficulty strikes the animals. Animal population increases are halted by malnutrition of the animals. The rate at which

Table 5.2

Sizes of Flocks Near the Research Site in April 1976 and April 1977

Flock Number	Animal Type	No. of Adult Females in April 1976	1977	Percent Change
1	Sheep	11	15	+36
	Goats	28	28	0
	Both	39	43	+10
2	Sheep	20	19	- 5
	Goats	35	26	-26
	Both	55	45	-18
3	Sheep	31	36	+16
	Goats	16	24	+50
	Both	47	60	+28
4	Sheep	22	19	-14
	Goats	19	17	-11
	Both	41	36	-12
5	Sheep	21	16	-24
	Goats	15	17	+13
	Both	36	33	- 8
6	Sheep	21	27	+29
	Goats	21	18	-14
	Both	42	45	+ 7
7	Sheep	51	58	+14
	Goats	56	65	+16
	Both	107	123	+15
Total of seven flocks	Sheep	177	190	+7
	Goats	190	195	+3
	Both	367	385	+5

Table 5.3

Average Numbers of Adult Females (Ewes and Does, Including Yearlings) in Four Flocks Near the Research Site Grazing Between November and April in Agricultural Years 1974-75 and 1976-77

Flock Number	Av. No. Ad. Females From Nov. to Apr.		Percent Change
	1974-75	1976-77	
1	45.5[a]	44.7[b]	-2
2	38.2[a]	48.5[c]	+27
3	48.7[a]	62.6[b]	+29
4	43.0[a]	54.8[b]	+27
Total of all four	175.4	210.6	+20

[a] Data from Bedoian and Bedoian, Table 13.6, Progress Report No. 4. They averaged data from each month from November to April.

[b] The average of:

No. for November = (No. On 29 September plus No. on 16 December) ÷ 2
No. for December = no. on 16 December
No. for January = (No. on 16 December plus No. on 17 February) ÷ 2
No. for February = No. on 17 February
No. for March = (No. on 17 February plus No. on 13 April) ÷ 2
No. for April = No. on 13 April

[c] In 1976-77, Flock #2 was observed only in September and April, when it had 58 and 45 adult females, respectively. This flock never left the vicinity of the project's site in 1976-77.

The average for 1976-77 of the other three flocks combined was 84% of their September average. If Flock #2 followed this trend, its 1976-77 average would have been 49 = 58 x 0.84.

The average during 1976-77 of the other three flocks combined was 7% larger than their average in April. If Flock #2 followed this trend, its 1976-77 average would have been 48 = 45 x 1.07.

The two methods give similar results. Thus (48 + 49) ÷ 2 = 48.5.

livestock populations recover from their latest catastrophe is affected by vegetational quality (see our later chapter on the production of lambs and kids) and by the number of animals necessary to satisfy basic human monetary and nutritional requirements.

The increase of the livestock population has undoubtedly adversely affected the range. While the rainfall increased annually between 1972-73 and 1975-76 (Novikoff, Progress Report No. 4 and 5), so did the livestock populations. In addition, less pastureland would have been available in 1975-76 than in 1972-73, because more land is planted into grain in years of higher precipitation (Bedoian, ibid.). By approximately doubling in density, livestock must have worked to the detriment of any vegetational recovery that would have been induced by the increased rainfall.

This period of increasing primary production was followed in 1976-77 by a severe drought and correspondingly low vegetational production; however, the livestock population again increased. The local people stated that they would not part with their animals until all forage, straw, hay and grain were exhausted. Such a practice would probably increase the desertization process.

A survey during May, 1977, indicated that most flocks would not leave the Chaabanian area during the summer, but rather would be supplemented with fodder and grain, some of which would be bought. Bedoian (ibid.) found a similar situation in 1972-73, when 50 percent of the total annual sheep and goat diet was fodder and grain, and 20 percent of the total caloric requirements were bought. We predict that fodder and grain during the summer, 1977, will maintain the lives of many animals which would otherwise die or be sold. These animals will eat much of the remaining vegetation -- vegetation that could not by itself support an animal because of its low quality and sparcity. Thus many more perennial plants will be destroyed than if the animals left the range. In addition, by May 1977 animals were already consuming much litter, including woody litter, and without litter soil erosion increases markedly (Novikoff, Progress Report No. 5). Finally, animals still present after the summer will make vegetational recovery during 1977-78 more difficult.

The History of Each Project Pasture

Methods.-- Between April 1976 and June 1977, we kept the records of the project flock, including its composition and dates of entry into and exit from the pastures. We examined project files to determine the flock composition and pasture utilization of previous dates.

An agricultural year was considered to begin with the first fall rains. At that time, any sheep or goats born before June became "adults." We know of no births occurring between early May and early October.

Stocking rate is defined in terms of animal days per hectare: (the average number of animals in the pasture) X (the number of days spent in the pasture) ÷ (the surface area of the pasture). This parameter is divided between adult days per hectare and young days per hectare. In this section, DZ refers to Dar ez Zaoui and HS refers to Henchir es Siane.

Results and discussion.-- Tables 5.4 through 5.12 present the history of each pasture controlled by the project. We have some uncertaintly about the surface areas designated for the pastures at Henchir es Siane, but will accept them as they are for the present.

A cursory examination of Tables 5.4 through 5.12 shows that the pastures have different histories. Such dissimilar histories should be considered when comparing the vegetation of the different pastures. The following points should be considered when comparing the spring pastures: C1, the mixed-flock pasture; C2, the sheep-only pasture; and C3, the goat-only pasture.

The mixed-flock pasture has been grazed less than either single-species pasture. Between May 1972 and April 1974, C1 received only 13 adult days/ha. Even the first portions of C2 and C3 were not acquired until early April, 1974. We must assume that they were grazed at normal local stocking rates during the preceding 2 years -- about 20 times as intensively as C1. By the first period when all three pastures were grazed simultaneously -- April 1974 -- plants in C1 should have displayed greater vigor, and possibly more preferred plants occurred in C1. After this time, even if equal stocking rates were maintained, C1 would very likely have shown improvement relative to C2 and C3. One reason for such improvment is that the preferred plants of C1, by now more abundant, would have suffered less per plant than the more scarce, preferred plants of C2 and C3.

However the stocking rates in the spring pastures did not become equal. In spring 1975, C1 received only two-thirds as much use as C2 or C3. Although C1 also received a small amount of use during the slow growth season, C1 should have improved relative to C2 and C3 during the course of the year.

According to a technician that has been with the project since its inception, C1 has always had less *Artemisia campestris* than C2 or C3. The first simultaneous vegetational analyses were not made on these pastures until shortly before their use in spring 1975. At that time, *A. campestris* was 0.2, 13.7, and 19.8 percent of the total standing crop, excluding wood, of pastures C1, C2 and C3, respectively. (These are our calculations and based on the original data. They differ from those presented by Dr. Novikoff in Section 2.2 of Progress Report No. 4, because he compared *A. campestris* including its wood with other plants excluding their wood.)

Since *A. campestris* is the only common, unpalatable plant in the spring pastures (see the chapter on dietary preferences), then C1 produced the largest percentage of palatable plants while C3 produced the lowest percentage of palatable plants. Since all three pastures had similar total productions, C1 would have had the most palatable production, while C3 would have had the least amount of palatable production. Given equal stocking rates, the palatable plants of C1 would have been less utilized than those of C2 or C3.

Precipitation at C1 is sometimes different from that of C2 and C3 (Bedoian, ibid. and Novikoff, Section 1.1 of Progress Report No. 5). Different amounts and different timing of rain may induce divergences in vegetational characteristics (Novikoff, ibid.).

Although we have not measured soil characteristics, they may be significant enough to cause divergent successional trends between the three spring pastures.

In summary, any differences between the range trends of C1, C2 and C3 involve more than just whether they are grazed by sheep and goats mixed, sheep alone, or goats alone. The comparisons of other pastures could be considered in a manner that is similar to the above discussion.

Some comment upon the photo essays of Report No. 5, particularly the frontispiece. Between May, 1972, and the time the picture was taken 3 years later, the different areas of Dar ez Zaoui each totaled between 0 and 150 adult days/ha, for an average overall of Dar ez Zaoui of 69 adult days/ha. Even if the neighbors had had only half as many animals during the 3 years as during 1976-77 (see Table 5.1), they still would have had about 0.3 adults/ha, or 330 adult days/ha over the 3 years. Thus the stocking rate of the project was only 20 percent as large as the neighbors'. Such management would obviously be expected to induce improvement in pastures.

For an additional reason, care should be taken in comparing the Dar ez Zaoui site with land immediately adjacent to it. The fence around Dar ez Zaoui creates a barrier. This barrier causes neighboring flocks to trail just outside the fence during their frequent, often daily, movements from one side of the study site to the other. Our observations indicated that land within 50 meters of the northwest and northeast sides of Dar ez Zaoui received considerably more grazing and trampling damage than is typical for nearby neighboring pastures.

Table 5.4

The History of Pasture A, the Fall Pasture

Other Names: Erg Djerba, Erg SiMahmond, The emergency pasture and rarely, P1.
Surface Area: Estimates vary from 8.8 ha to 10.0 ha. The pasture includes about 1 ha of mostly bare, recently cultivated land. In the calculations below, we will use the figure of 9.0 ha.
Acquired: sometime in 1974
Amounts of use since acquisition:

Grazing Period			Av. No. of Animals						Animal Days/ha		Supplements during Period
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	
Agricultural Year 1974-1975											
18 Mar	18 Apr	32	3	13	8	3	8	6	96	50	None
Agricultural Year 1975-76											
11 Dec	12 Jan	33	7	41	25	6	26	10	293	128	1000 kg alfalfa hay & 360 kg barley grain
16 Apr	17 Apr	2	4	30	30	4	32	22	16	12	None
Total for Agricultural Year 1975-1976									309	140	See above
Agricultural Year 1976-77 until June											
19 Oct	5 Nov	18	3	41	0	4	44	0	184	0	None
20 Feb	6 Mar	14	3	31	32	3	33	37	109	107	40 kg mixed hay, 150 kg barley grain
Total for Agricultural Year 1976-1977 before June									293	107	See above

Table 5.5

History of Pasture B, the Winter Pasture

Other Names: H.S. V, "the 40-hectares", the "early spring" pasture, treatment D in Section 2.5.1 of Report No. 5 and rarely, PII.
Surface Area: Originally estimated 40 ha, now corrected to between 32 and 38 ha. In the calculations below, we will use the figure of 35.0 ha.
Acquired: Early fall, 1975
Amounts of use since acquisition:

Entry	Grazing Period Exit	No. Days	Average No. Animals Rams	Ewes	Lambs	Bucks	Does	Kids	Animal Days/ha Adult	Young	Supplements during Period
Agricultural Year 1975-76											
24 Feb	15 Apr	52	7	40	30	5	25	22	114	77	None
Agricultural Year 1976-77											
26 Nov	16 Dec	21	3	40	18	4	42	16	53	20	280 kg barley grain to mothers
17 Dec	21 Jan	36	3	36	28	3	35	28	79	58	700 kg barley grain to mothers 700 kg mixed hay to everyone
28 Jan	15 Feb	19	3	36	34	3	35	38	42	39	500 kg barley to mot 400 kg mixed hay to everyone
Total for the agricultural year 1976-1977 prior to June									174	117	1500 kg barley 1100 kg hay

Table 5.6

History of Pasture C1, the Spring Mixed-flock Pasture

Other Names: C[1], DZ III, treatment G in Section 2.5 of Report No. 5 and, rarely, III A.
Surface Area: 15.2 ha in 1973, 1974 and 1975, 15.6 ha in 1976 and 16.2 ha in 1977
Composition: The original 15.2 ha was DZ III. In April 1976, 0.4 ha was added from the part of DZ IV lying in the northern corner of the validation site. In February, 1977, 0.6 ha was added for a path to Pasture C1, taking it from the southwestern portion of DZ IV. See Map 1 of Report 2.
Acquired: May 1972
Amounts of grazing since acquisition:

Grazing Period			Average No Animals						Animal Days/ha		Supplements during Period
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	
Agricultural Year 1972-73											
6 Apr	11 Apr	5.5	0	6	7	0	0	0	2	2.5	Unknown
14 Apr	12 May	28	0	0	0	0	6	9	11	16.6	Unknown
Total in Agricultural Year 1972-73									13	19	Unknown
Agricultural Year 1973-74											
25 Apr	25 May	31	8	11	7	7	12	7	77	29	Unknown
Agricutural Year 1974-75											
19 Apr	29 May	41	3	13	9	3	8	6	73	40	None
30 May	18 July	50	3	9	6	3	8	6	76	39	None
23 Sep	30 Sep	8	7	32	22	6	27	28	38	26	Some, amount unknown
Total during Agricultural Year 1974-75									187	105	Some, amount unknown
Agricultural Year 1975-76											
18 Apr	9 July	43[a]	2	15	12	2	16	10	96	61	None
10 July	18 Aug	40	1	10	6	2	11	6	62	31	37 kg alfalfa hay to young
Total during Agricultural Year 1975-76									158	92	See above
Agricultural Year 1976-77 prior to June											
20 Mar	18 Apr	30	1	11	12	1	10	11	43	43	None
19 Apr	13 May	25	1	9	12	1	9	16	31	43	None
Total during Agricultural Year 1976-77 prior to June									74	86	None

[a] For 82 days, from 18 April until 9 July, Pasture D1 (14.3 ha) was grazed at the same time and with the same animals as the mixed spring pasture (15.6 ha). Thus the proportion of use occurring in the mixed spring pasture was approximately .52=(15.6 ha ÷ (15.6 ha + 14.3 ha)). Hence the figure used for the length of grazing was 43 days = (.52 x 82 days).

Table 5.7

History of Pasture C2, the Spring Sheep-only Pasture

Other Names: C", HS 2 in Figure 2.1 of Report No. 3, HS II and Treatment E in Section 2.5 of Report No. 5, HS III or III B on data sheets.
Surface Area: 10.75 ha in spring 1974 and spring 1975, between 15.1 and 15.7 in spring 1976-- 15.4 will be used below, between 14.5 and 15.5 in spring 1977--15.0 will be used below
Acquired: The original area of 10.75 ha was acquired in early April 1974. About 5 ha were added sometime betweenspring 1975 and spring 1976. In November 1976, 0.5 was removed for an animal shelter.
Amounts of grazing since acquisition:

Grazing Period			Average No. Animals						Animal Days/ha		Supplements during Period
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	
Agricultural Year 1973-74											
25 Apr	25 May	31	9	15	9	0	0	0	69	26	Unknown
Agricultural Year 1974-75											
19 Apr	18 July	91	4	23	17	0	0	0	229	144	None
Agricultural Year 1975-76											
18 Apr	9 July	82	2	15	12	0	0	0	91	64	None
10 July	17 Aug	39	3	21	11	0	0	0	61	28	None
Total during Agricultural Year 1975-76									152	92	None
Agricultural Year 1976-77 prior to June											
20 Mar	18 Apr	30	2	20	21	0	0	0	44	42	None
19 Apr	7 May	19	2	18	12	0	0	0	55	15	None
Total during Agricultural Year 1976-77 prior to June									69	57	None

Table 5.8

History of Pasture C3, the Spring Goat-only Pasture

Other Names: C[1], HS 1 in Figure 2.1 of Report No. 3, HS II on data sheets, HS III and treatment F in Section 2.5 of Report 5, rarely III c.
Surface Area: 9.54 ha in spring 1974 and spring 1975, between 14.4 and 14.9 ha in spring 1976 -- 14.7 will be used below, between 14.0 and 14.5 ha in spring 1977--14.3 will be used below.
Acquired: The original area of 9.45 ha was acquired in early April 1974. Approximately 5 ha were added sometime between spring 1975 and spring 1976. In November 1976, 0.5 was removed for an animal shelter.
Amounts of grazing since acquisition:

Grazing Period			Average No Animals						Animal Days/ha		Supplements during Period
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	
Agricultural Year 1973-74											
25 Apr	25 May	31	0	0	0	13	13	11	85	36	Unknown
Agricultural Year 1974-75											
19 Apr	18 July	91	0	0	0	3	20	19	221	183	None
Agricultural Year 1975-76											
18 Apr	9 July	82	0	0	0	2	16	10	100	56	None
10 July	17 Aug	39	0	0	0	2	22	11	64	29	None
Total during Agricultural Year 1975-76									164	85	None
Agricultural Year 1976-77 prior to June											
20 Mar	18 Apr	30	0	0	0	2	23	25	52	52	None
19 Apr	7 May	19	0	0	0	2	19	12	28	16	None
Total during Agricultural Year 1976-77 prior to June									80	68	None

Table 5.9

History of Pasture D1, the Early Summer Pasture

Other Names: D^1, Destructive Sampling Zone, Zone de Coupe et Prelevement on most data sheet, rarely P4A.
Surface Area: 14.3 ha total
Composition: Northeastern portion of DZ II A (3.7 ha), northeastern portion of DZ II B (5.2 ha), nothwestern portion of DZ II B (3.8 ha), all of DZ I (1.6 ha), see Map 1 of Report 2.
Acquired: May 1972
Areas grazed and surface areas used for the calculations below:
In 1973-74 and 1974-75 only, all of DZ II B (9.0 ha) grazed. (See Table 10 for the rate on NE DZ II B at that time.) After 18 April 1976 all of D1 was grazed together.
Amounts of grazing:

Grazing Period			Average No. Animals						Animal Days/ha		Supplement
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	during Period
Agricultural Year 1973-74 (only II B grazed)											
25 May	Unknown	30	8	11	7	7	12	7	127	47	Unknown
Agricultural Year 1974-75 (only II B grazed)											
19 July	22 Sept	66	7	32	22	6	28	29	535	374	Some, but amount unknown
Agricultural Year 1975-76 (other than NE DZ II B in Jan and Feb)											
18 Apr	9 July	39[a]	2	15	12	2	16	10	95	60	None
Agricultural Year 1976-77 prior to mid-June											
28 Sept	18 Oct	21	3	41	0	4	44	0	135	0	None
15 May	16 June	33	3	27	14	3	28	18	141	74	300 kg barley grain
Total during agricultural year 1976-77 by mid-June									276	74	See Above

[a] This period from 18 April to 9 July had 82 days, but they were shared with the pasture C1.

Table 5.10

History of Pasture D2, the Late Summer Pasture

Other Names: D" ungrazed area, Mise en Defens on data sheets, DZIV and Treatment A^1 (winter grazing) in Section 2+5 of Report 5 and rarely, 4B.
Surface Area and Composition: Pasture D2 is composed of parts of DZ IV (15.0 ha--see Map 1, Report 2). None of DZ IV was grazed between May 1972, the time of acquisition, and October 1975.

In October 1975 a 0.8-ha strip along the northern border of the study site was separated from DZ IV and remains ungrazed at the time of this writing; except when neighboring animals sometimes slip under the fence or through the fence.

The remaining 14.2 ha of DZ IV was grazed from 1 October until 10 December 1975. This use was divided between agricultural years 1974-75 and 1975-76 by when the rains began on 27 October. We found some indications that the northern portion of DZ IV was grazed many times more intensely than the southern portion.

From 13 January until 9 February only 6.1 ha (which ?) of DZ IV were grazed, in conjunction with 5.2 ha of northeastern DZ II B. (So 11.3 ha used below).

In early April 1976, 0.4 ha was given to C1 out of the northern portion of DZ IV; a 0.2-ha strip along the western border of DZ IV was again excluded from grazing; and 2.8 ha of southeastern DZ IV were given to the wild animal studies. Thus in summer 1976, pasture D2 totaled 10.8 ha. In Spring 1977, 0.6 ha was given for a path C1, from the southeastern border of D2. Thus summer 1977, if no further changes occur, will have 10.2 ha in D2.

Amounts of Grazing:

Grazing Period			Average No. Animals						Animal Days/ha		Supplement
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	During Period
Agricultural Year 1974-75											
1 Oct	27 Oct	27	7	32	22	6	27	27	137	93	Some, amount unknown
Agricultural Year 1975-76											
28 Oct	10 Dec	44	7	41	14	6	26	5	248	59	2500 kg grain and hay
13 Jan	9 Feb	28	7	41	28	5	25	15	193	106	None
18 Aug	27 Sep	41	3	29	15	3	31	13	251	106	None
Total During Agricultural year 1975-76 most used portion									292	271	

Table 5.11

History of the "Emergency" Pasture

Other Names: HS 3 and HS 4 combined in Figure 2.1 of Report No. 3 and in Table 13.1 of Report No. 5, HS I and IV in Section 2.5 of Report No. 5 and on most data sheets, Treatment C in Section 2.5 of Report No. 5 and sometimes the pasture by the old grisha on data sheets.
Surface Area: Between 14.8 and 15.4 ha, depending upon the document used as the source. Below we shall employ 15.0 ha during 1974-75, then 14.0 ha as some of the pasture was planted in 1975-76 and 1976-77.
Acquired: Early April 1974
Amounts of grazing since acquisition:

Grazing Period			Average No. Animals						Animal Days/ha		Supplements during Period
Entry	Exit	No. Days	Rams	Ewes	Lambs	Bucks	Does	Kids	Adult	Young	
Agricultural Year 1974-75											
4 Dec	18 Feb	77	3	13	8	3	8	6	138	72	Much, unknown amount
Agricultural Year 1975-76											
10 Feb	23 Feb	14	7	41	28	5	25	16	78	44	None
Agricultural Year 1976-77 prior to June											
6 Nov	25 Nov	20	3	40	6	4	44	3	130	13	70 kg barley to mothers
22 Jan	27 Jan	6	3	36	32	3	35	32	33	27	140 kg barley to mothers and 120 kg hay to everyone
16 Feb	19 Feb	4	3	36	35	3	35	38	22	21	100 kg barley to mothers 80 kg hay to everyone
9 Mar	19 Mar	11	3	31	33	3	33	37	55	55	None
8 May	13 May	6	2	18	12	2	19	12	18	10	50 kg hay to everyone
Total during the Agricultural Year 1976-77 prior to June									258	126	310 kg barley, 250 kg hay

Table 5.12

History of Pasture F, the Ungrazed Area

Surface Area: 8.0 ha

Composition: DZ IIc (1.4 ha), the southwestern portion of DZ II A (3.8 ha), and the southeastern edge of DZ IV (2.8 ha).

Acquired: May, 1972

Amounts of use since acquisition: All of the area has been used for destructive sampling. Only one portion from DZ IV has ever been grazed. For information about DZ IV, refer to the table on pasture D2.

PART III

PROCESS STUDIES

CHAPTER 6

DEMOGRAPHY OF PLANT SPECIES

by Georges Novikoff

Objectives

Changes in vegetation composition, such as occur with degradation due to improper grazing, or with improvement due to protection from grazing and appropriate range management measures, result from certain demographic patterns in the constituent plant species. Species which increase do so by vitue of increased seed production, seed survival, germination, seedling survival, survival of older plants, or some combination of these. Species which decrease do so by virtue of reduced rates in one or more of these same processes. Vegetation changes can be measured and described empirically, but elucidation of the mechanisms of those changes depends on measuring in detail the demography of the constituent species.

Demographic characteristics of the vegetation are important to the fauna. The abundance of granivorous species (e.g. rodents, ants, birds) may importantly depend on the kinds and numbers of seeds produced. These granivores, in turn, may importantly affect plant demography through their seed predation. Similar two-way relationships exist between seedlings and some herbivorous species. Consequently, an understanding of plant demography is an important link in explaining vegetation changes, population behavior of certain elements of the fauna, and causal relationships between the two. For these reasons, effort has been directed to demographic studies of some of the plant species, and 1974-76 results are reported herewith.

Fruit and Seed Production

Methods.-- Fruit and seed production were studied in 1976 in the following plant species: *Plantago albicans*, *Zolikoferia resedifolia* ssp. *eu-resedifolia*, *Helianthemum lipii* var. *sessiliflorum*, *Argyrolobium uniflorum*, *Linaria fruiticosa* ssp. *aegyptiaca*, *Nolletia chrysocomoides*.

The number of fruits produced on individual plants of each of these species was counted in random samples of individuals and mean numbers of fruits per plant were calculated. Individual seeds in each fruit were than counted, and mean numbers of seeds per fruit calculated. With these calculations and estimates of the number of individual plants per ha, it was than possible to estimate the number of seeds produced per ha in 1977.

Results.-- The numbers of plants on which fruits were counted, total number of fruits counted, and the mean number of fruits per plant are shown in Table 6.1. The individual plants used for these observations were the same as those used for the root/shoot regressions in Chapter 2.

Random samples of fruits for the six plant species were dissected and their seeds counted. Mean numbers of seeds per fruit were then calculated and these are shown in Table 6.2.

Table 6.1

Fruit Production of Six Important Plant Species in Spring 1977 at Dar ez Zaoui

Species	No. Individual Plants Counted	Total Fruits Counted	Av. Fruit Prod. per Plant
Plantago albicans	42	327	7.7[1]
Zollikoferia resedifolia ssp. eu-resedifolia	42	1,592	37.9
Linaria fruticosa spp. aegyptiaca	10	10,658	1,065.8
Nolletia chrysocomoides	10	751	75.1
Argyrolobium uniflorum	10	972	97.2
Helianthemum lipii var. sessiliflorum	10	1,270	127.0

[1] Spikelet of several fruits.

Table 6.2

Numbers of Seeds per Fruit for Six Species in Spring 1977 at Dar ez Zaoui

Species	No. Fruits Samples	Total No. Seeds Counted	Av. No. Seeds per Fruit
Zollikoferia resedifolia ssp. eu-resedifolia	16	483	30.2
Nolletia chrysocomoides	50	2,184	43.7
Helianthemum lipii var. sessiliflorum	100	1,975	19.8
Argyrolobium uniflorum	80	684	8.6
Plantago albicans	110	3,995	36.3

With a knowledge of the mean number of seeds per fruit, and the number of fruits per plant, it was then possible to calculate the number of seeds per plant (Table 6.3). Knowing the mean number of plants of these species per hectare on the basis of the vegetation sampling reported in Chapter 2, we were then able to calculate the number of seeds produced per hectare in Pasture C, at Dar ez Zaoui during 1977 (Table 6.3).

Table 6.3

Numbers of Seeds Produced per Plant and per Hectare in 1977, Dar ez Zaoui Pasture C_1

Species	Av. No. Fruits per Plant	Av. No. Seeds per Fruit	Av. No. Seeds per Plant	No. Plants and Seeds per Hectare: Nebka Subunit: No. Plants per ha	Nebka Subunit: No. Seeds per ha	Normal Subunit: No. Plants per ha	Normal Subunit: No. Seeds per per ha
	A	B	C=AxB	D	E=CxD	F	G=CxF
Plantago albicans	7.7	36.3	279.5	142,600	39,856,700	89,335	24,969,133
Zollikoferia resedifolia ssp. eu-resedifolia	37.9	30.2	1,144.6	61,875	70,822,125	43,659	49,972,091
Helianthemum lippii var. sessiliflorum	127.0	19.8	2,514.6	27,800	69,905,880	30,870	77,625,702
Argyrolobium uniflorum	97.2	8.6	835.9	43,500	36,361,650	51,582	43,117,394
Linaria fruticosa ssp. aegyptiaca	1,065.8	1.0	1,065.8	1,000	1,065,800	2,131	2,271,220
Nolletia chrysocomoides	75.1	44.0	3,304.4	5,150	17,017,660	24,474	80,871,886

Seedling Populations

Methods.-- As described in Progress Report No. 5, 12 1-m^2 quadrats were placed at random in the Dar ez Zaoui destructive sampling area, 6 in nebka soil type and 6 in the normal soil type. Numbers of seedlings were counted in each of these quadrats on December 5, January 5, and February 5 in 1974-75 and 1975-76. The purpose of these counts was to follow the development and survival of seedlings during these two seasons, and to relate them to environmental factors. A preliminary analysis of the results is now of interest.

Results.-- The numbers of seedlings by species at each count are shown in Table 6.4 for the six quadrats in the nebka soil type, and the totals are graphed in Figure 6.1 along with the soil moisture measured at approximately the time of the seedling counts. Trends in the 2 years are virtual mirror images of each other. Total seedling numbers declined slightly between the December and January counts in 1974-75, although this was strongly weighted by the trends in some of the most abundant species; nearly half (12) of the 27 species actually increased during the period. Seedling numbers then increased sharply between the January and February counts.

During 1975-76, seedling numbers increased between the December and January counts and declined sharply by the February count. However, even with the January-February count, five of the 27 species increased during this period.

These between-year variations in seedling numbers are closely paralleled by between-year differences in soil moisture (Figure 6.1). Soil moisture was relatively low during November-December of 1974-75 at which time the number of seedlings was substantially below the 1975-76 level. By early February, winter rains had roughly doubled the soil moisture, and by this date seedling numbers had increased sharply.

In 1975-76, soil moisture was already high in November and had increased by early January. Correspondingly, seedling numbers had reached high levels in early December and early January. By February, soil moisture had fallen to half its early January level. By this time, seedling numbers had declined, presumably due to declining moisture and competition among the plants for that diminishing supply.

It is of some interest to explore the role of temperature in seedling development and survival. In Tunisia, native plants only grow above a 10°C threshold. Growth is enhanced as temperatures rise above this level. One means of quantifying the thermal environment during the growth period is to calculate accumulated degree-days: i.e. add the mean temperature for each day to a daily accumulating sum that dates back to some starting date. Thus, the accumulated degree-days at the end of a 30-day month with mean daily temperatures of 20°C is 600.

Table 6.4

Number of Seedlings Counted in Six 1-m^2 Quadrats During the 1974-75 and 1975-76 Winters at the Dar ez Zaoui Destructive Sampling Area

Species	1st Count (Dec. 5)		2nd Count (Jan. 5)		3rd Count (Feb. 5)	
	1974-75	1975-76	1974-75	1975-76	1974-75	1975-76
Annuals and Biennials						
Cutandia divaricata / *Schismus barbatus*	5955	4505	5163	3716	6815	2502
Ifloga spicata	2219	3357	2211	6315	3624	5497
Hordeum murinum	767	2764	1015	1697	1535	911
Cleome arabica	81	16	50	5	41	8
Paronychia argentea	30	0	21	58	28	46
Plantago albicans	179	323	135	613	205	279
Zollikoferia resedifolia	27	52	46	75	57	33
Lotus pusillus	5	295	43	79	51	70
Hedysarum spinosissimum	5	30	2	42	2	41
Medicago littoralis	98	395	78	467	70	246
Hippocrepis multisiliquosa	8	32	15	32	7	47
Matthiola kralikii	293	136	288	310	369	184
Malva aegyptiaca	198	208	106	146	161	50
Asphodelus fistulosus	398	563	350	565	435	296
Senecio delphinifolius	22	0	36	49	32	14
Bupleurum lanceolatum	0	14	29	0	40	0
Chenopodium murale	0	42	0	68	0	25
Filago spathulata	0	0	67	616	147	222
Daucus syrticus	80	331	203	277	293	189
Adonis dentata	0	6	0	432	0	164
Small-sized Perennials						
Argyrolobium uniflorum	9	10	27	0	35	5
Nolletia chrysocomoides	0	0	2	1	3	3
Linaria aegyptiaca	0	0	2	2	6	1
Helianthemum sessiliflorum	1	0	1	0	4	2
Astragalus gyzensis	0	0	0	2	0	0
Rhanterium suaveolens	91	66	100	152	101	28
Total No. of Seedlings	10,466	13,145	9,990	15,719	14,060	10,863

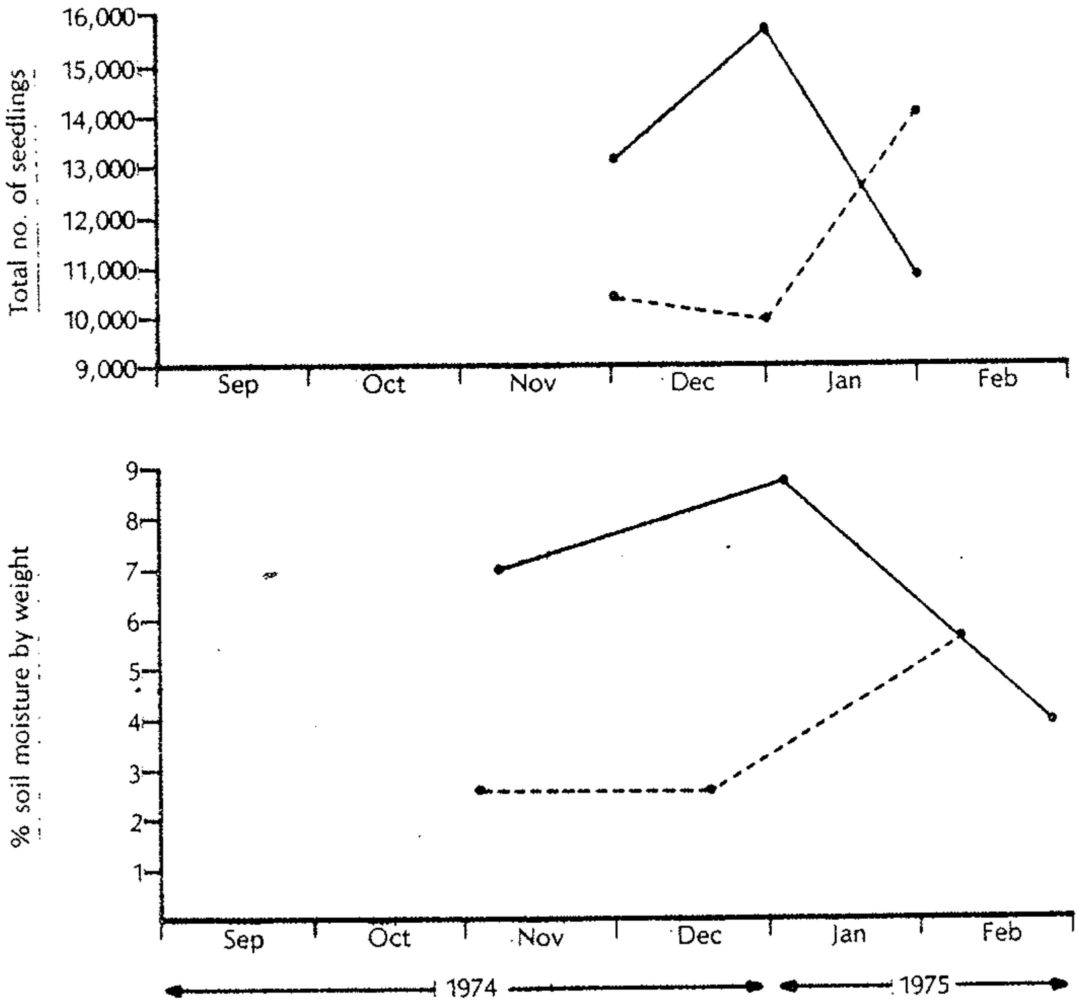


Figure 6.1 Numbers of seedlings and soil-moisture measurements in fall and winter, 1974-1975.

Such degree-day calculations were made for the Dar ez Zaoui sites for the 2 years 1974-75 and 1975-76 starting with the first rains each fall and accumulating until the third seedling counts were made in early February. These are summarized in Table 6.5

Table 6.5

Degree-days Accumulated from the First Fall Rains to Each of the Seedling Counts at Dar ez Zaoui, 1974-75 and 1975-76

Accumulation Period	Accumulated Degree-days by Year	
	1974-75	1975-76
From 1st rains (early Nov.) to 1st count (Dec.5)	1,422	471
From 1st count to 2nd count (Jan. 5)	354	321
From 2nd count to 3rd count (Feb. 5)	348	321
Total: 1st rains to 3rd count	2,124	1,113

The 1974-75 growing season was considerably warmer than 1975-76, owing largely to the warm November temperatures. Despite this fact seedling emergence occurred earlier in 1975-76 due apparently to the more favorable moisture conditions at an earlier date (Figure 6.1).

CHAPTER 7

TEMPORAL ACTIVITY PATTERNS OF THE WILD FAUNA

by R.J. Muir and H. Heatwole

Ants

Presence and absence samples.--

Method: As in 1974, 1975 and 1976, at each seasonal sampling of thermal microclimate, active ants were collected each hour over a 24 hr period. Ants were later identified and their activity patterns determined according to their presence or absence in the hourly samples. Results were examined in conjunction with environmental temperature data taken at the same time. Only results from autumn 1976 and winter 1976-77 are given here as the study was terminated with the winter sample.

Results: Though only two seasons were examined, results followed the trend observed in 1974-76. In the warmer, autumn 24 hr period most ant species were active at night (Cat. No. 630,684,748). One was active over the whole 24 hr (Cat. No. 601), one was crepuscular (Cat. No. 741), and only one actively foraged in the hottest part of the day (Cat. No. 653). All species but Cat. No. 601 in autumn showed a limited diel cycle (Fig. 7.1a).

In the cooler winter sample there was a shift from the nocturnal habit to a diurnal activity pattern. Four species foraged in the hottest part of the day (Cat. Nos. 653, 741, 601 and 748). One species, normally nocturnal, also foraged in the morning and afternoon (Cat. No. 684). Two species were nocturnal (Cat. Nos. 630 and 1056). At the coldest part of the day (0600 hrs) none of the ant species were active (Fig.7.1b).

Activity related to food gathering.-- Presence or absence results show only the limits of activity periods and give no indication of the intensity of activity or the numbers of individuals involved in activity periods. By measuring numbers of individuals actually foraging, it is possible to plot activity peaks of each species and to compare responses to the diel and annual cycles. Those species active but not foraging may be deleted from calculations.

Methods: During counts on seed predation by the two harvesting ants Messor A (Cat. No. 748) and Messor B (Cat. No. 741), numbers of foragers were recorded hourly for each active nest. The number of ants successfully gathering seeds per hr was used as the unit of measurement in this study. Hourly results over three 24 hr periods in autumn 1976, winter 1976-77 and spring 1977 were plotted for both Messor A and Messor B (Fig. 7.2).

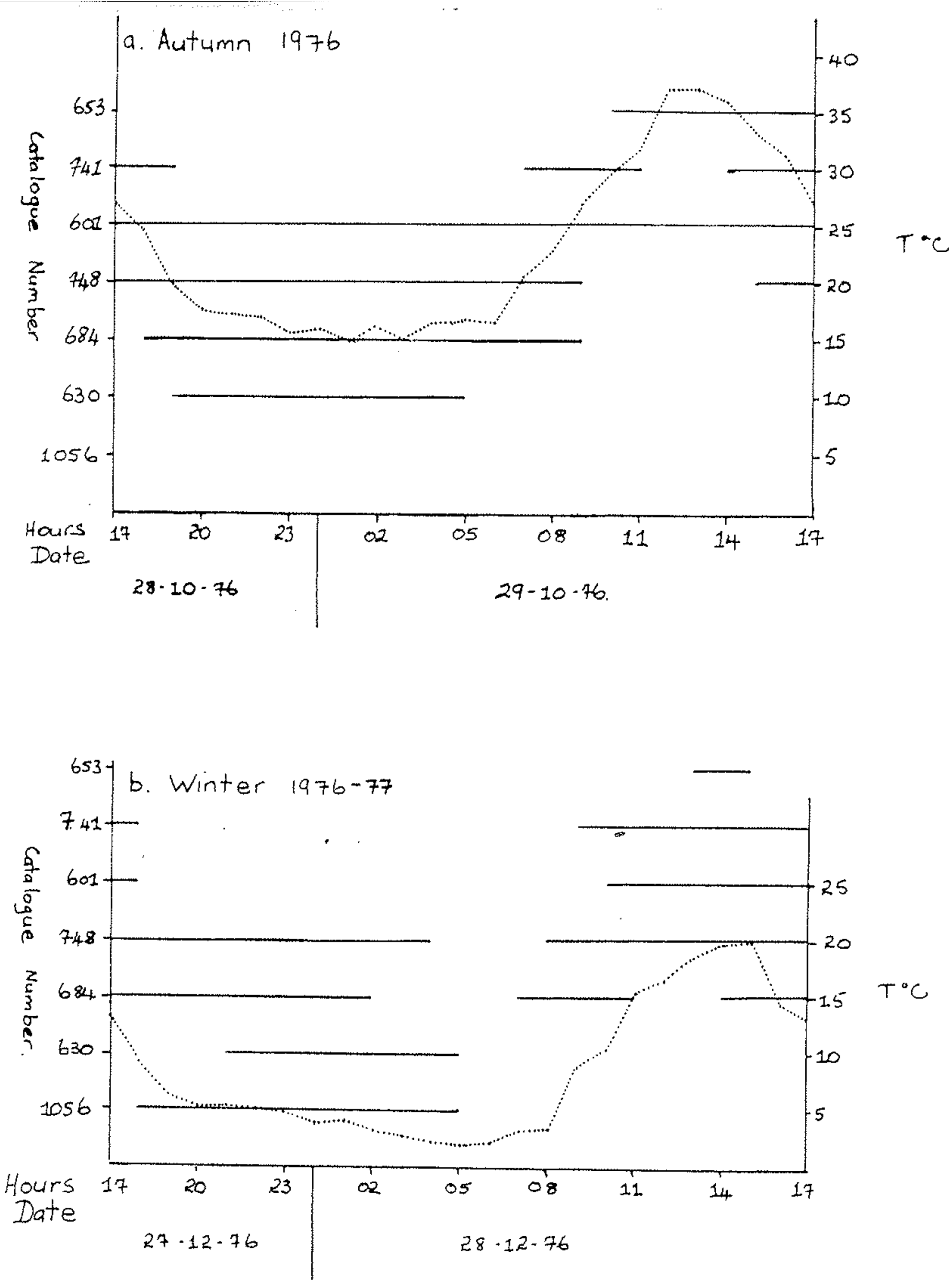
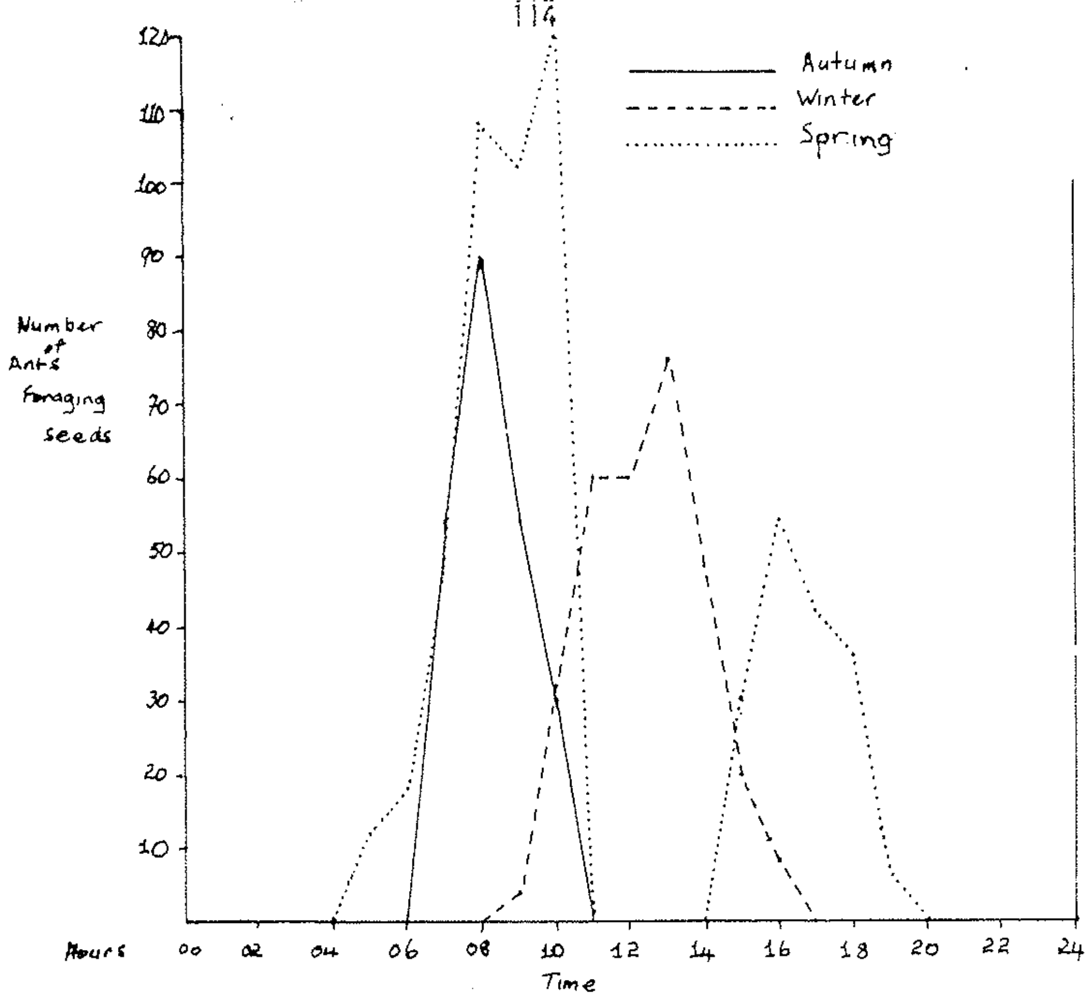


Figure 7.1. Presence or absence activity patterns of seven ant species over 24 hour periods in autumn 1976 and winter 1976-77. Ground surface temperatures in the open are shown for the same periods.



b. Messor B.

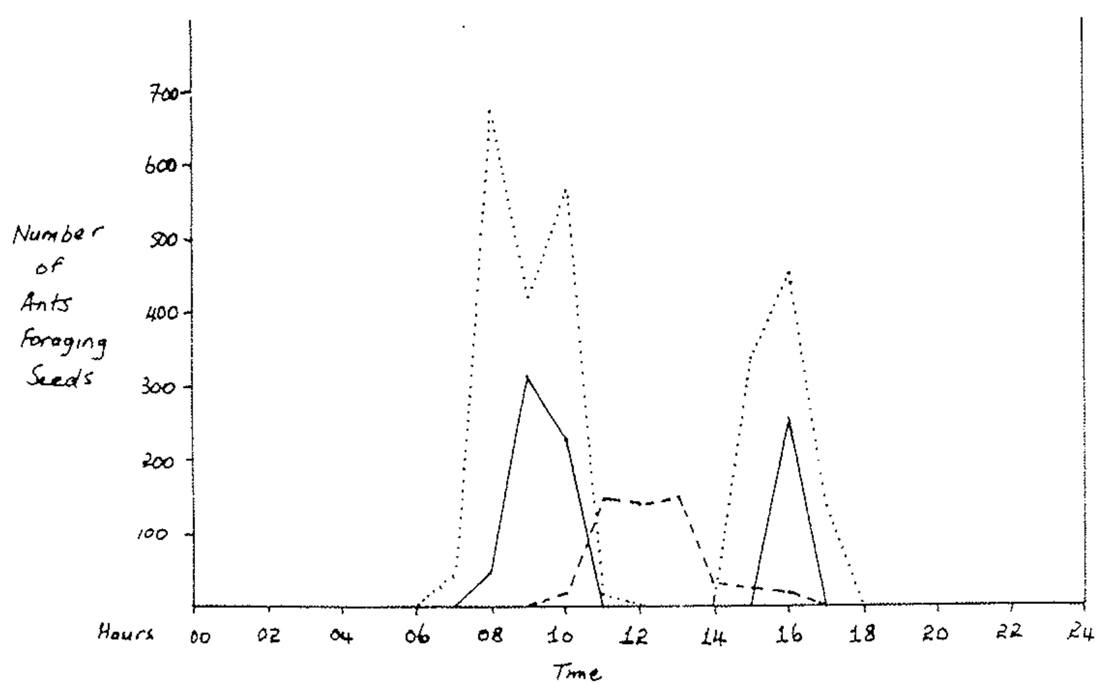


Figure 7.2. Food-gathering activity pattern for Messor A and Messor B over three 24 hour periods at different seasons between autumn 1976 and spring 1977.

Results: Results generally confirmed presence and absence results but with a reduction in duration of activity. Neither Messor A nor Messor B were found to forage more than 11 hrs per day (Fig. 7.2). Presence and absence data showed Messor A to be active for 21 hrs in winter but only actively foraging seeds for 8 of those hrs (Figs.7.1b and 7.2a). For both species there was a pronounced change in foraging time over the three seasons studied. Spring and autumn results showed a bimodal pattern of activity with a period of activity in the morning and one in the afternoon. Messor A was an exception in autumn where there was no afternoon mode (Fig. .2a). In winter there was a shift to a single mode in the middle of the day. As in 1975 and 1976, the highest intensity of foraging was found to be in spring for both species (Fig. 7.2).

Relative numbers of active colonies by season.--

Method: As in 1975 and 1976, population data were used to indicate numbers of active colonies per ha for each species over the seasons. In autumn and winter 1976-77 all ant species were included in the study. In spring 1977 only the two harvesting ant species, Messor A and Messor B, were studied. The total area sampled to obtain the colony number per ha was 1600 m^2.

Table 7.1

Number of Active Ant Colonies per Hectare in Autumn, Winter and Spring 1976-77[1]

	No. Colonies per Ha by Season		
Cat. No.	Autumn 1976	Winter 1976-77	Spring 1977
684	562.5	700	
795	19.0	—	
741	141.0	119 + 6X	122 + 31X
748	44.0	44 + 137.5X	78.0
601	31 + 6X	31.0	
1601	12.5	—	
673	25.0	—	
630	12.5	16.0	
606	6.0	19.0	
653	—	12.5	
Totals	853.5, H=185	941.5, H=163	H=200.0

X = Young colonies and colony founding queens
H = Harvesting colony total
[1] Only Messor species studied in spring 1977.

Results: The results are summarized in Table .1. Numbers of active Messor colonies remained relatively uniform over the three seasons with the exception of a large increase in Messor A colonies in spring. This recruitment probably came from the 137.5 per ha colony founding queens of Messor A detected in winter. Two species, 1601 and 673, had colonies active in autumn but not in winter, while one species (653) was active in winter but not in autumn. The general rise of colony number between autumn and winter was due mainly to a large increase in the number of active 684 colonies.

Discussion: Though there are insufficient data here to draw firm conclusions, when considered with data from other years, certain trends appear to be maintained. The ant species show marked patterns of activity on a colony and individual level over the seasonal cycle and at the level of the individual over the diel cycle.

Individuals of all species show an activity response to daily and seasonal temperature cycles. Response to daily temerature cycles is expressed in each species as a period of activity and a period of quiescence over the 24 hr interval (Figs. 7.1 and 7.2). Within the framework of activity period, each species demonstrates peaks of foraging behavior which indicate the most important parts of the activity period (Fig. 7.2). The different species have adopted temporal segments of the diel cycle in accordance with their behavioral response to the temperature or photoperiod cycle. Thus heat-adapted 653 forages toward the middle of the day, and nocturnal 630 and 1056 forage at night. Other species have adopted intermediate times (Fig. 7.1).

Response by individuals to seasonal temperature cycles is generally a change in the pattern of daily activity. Foraging times and peaks change in sympathy with temporal shifts in the range of microclimate temperatures favored for foraging by each species. Between cooler and warmer seasons, those species active in the daytime shift their activity period toward a crepuscular or nocturnal pattern, with activity peaks often splitting from a single peak at midday to morning and evening peaks (Figs. 7.1 and 7.2).

Though little can be seen in the autumn and winter results shown here, numbers of active colonies show marked changes from season to season throughout the year (See Progress Report No. 5). Particularly important are the first heavy rains following summer which caused a four-fold increase in the number of active colonies in autumn 1975. The autumn records in 1976 were taken after the first rains and active colony numbers were quite high. There was only a slight increase in active colony numbers for the winter sample taken months later (Table 7.1). One trend continuing in 1976 results, was the increase in numbers of active colonies of the scavenger ant (Cat. No. 684). The chief potential competitor of Cat. No. 684, Cat. No. 601, showed a 30% decrease in active colony numbers from 1975 results. Notably, Cat. No. 684 and Cat. No. 601 are principally nocturnal and diurnal respectively, though each will continue activity into the other's temporal domain if they have mobilized about a food source.

The harvesting ants show a trend of increasing colony number from winter to spring, probably in response to increased seed availability and intrinsic motivation to feed pre-adult stages which are present in spring.

The low rainfall of the 1976-77 rainfall season (68.6mm) compared with 1973-74 (94.2mm), 1974-75 (174.2mm) and 1975-76 (497mm) does not seem to have influenced active colony numbers as yet. It is expected that with the complex social system, there will be a considerable time lag before the precipitation change is felt at the colony level.

There is apparently no reversal of trends characteristic of 1974-76; and newly invaded species Cat. Nos. 1288 and 1289, usually found closer to the coast, appear to be continuing to expand (though still not recorded in sample areas). It remains to be seen if these species will disappear and if Cat. No. 684 will begin to decrease in colony numbers if present dry conditions persist into the 1977-78 rainfall season.

It is apparent that dry conditions have begun to influence ant activity on the individual level. For example, in the harvesting ants, activity intensity (number of seeds foraged per hour) is much lower in autumn and spring 1976-77 than it was in 1975-76. There is still a large reservoir of seeds from the 1976 spring available for the ants to forage (Hedysarum, Daucus and Medicago). Once this reservoir and the relatively poor seed supply from the 1977 spring are depleted, dramatic changes might be noted in the harvesting ant population on a colony as well as an individual level.

Large Coleoptera (Tenebrionidae, Carabidae)

Methods.-- A presence-absence study was conducted with the large Coleoptera between autumn 1976 and winter 1976-77 using the same method applied to the ants, over 24 hr periods. To measure intensity, transect counts were conducted on a 5 m wide, 320 m long transect in autumn 1976, winter 1976-77 and spring 1977. All large Coleoptera were counted at two hr intervals over 24 hrs for each season. Activity patterns were recorded against time on a density basis.

Results.-- Presence-or-absence results showed that, as with the ants, each Coleopteran species was active for a limited portion of the diel cycle in both autumn and winter. In autumn Cat. Nos. 1549, 641D, 641C and 706 were nocturnal. Cat. No. 641 was nocturnal and crepuscular. Cat. No. 640 was mainly diurnal, while Cat. No. 645 was diurnal (Fig.7.3a).

No species were active at the hottest part of the diel cycle. (Fig. 7.3a). There was a temporal shift of activity time between autumn and winter: Cat. No. 706 became crepuscular, Cat. No. 641 fully diurnal and Cat. No. 645 became active at the hottest part of the day. No species were active at the coolest part of the diel cycle or for most of the night (Fig. 7.3b).

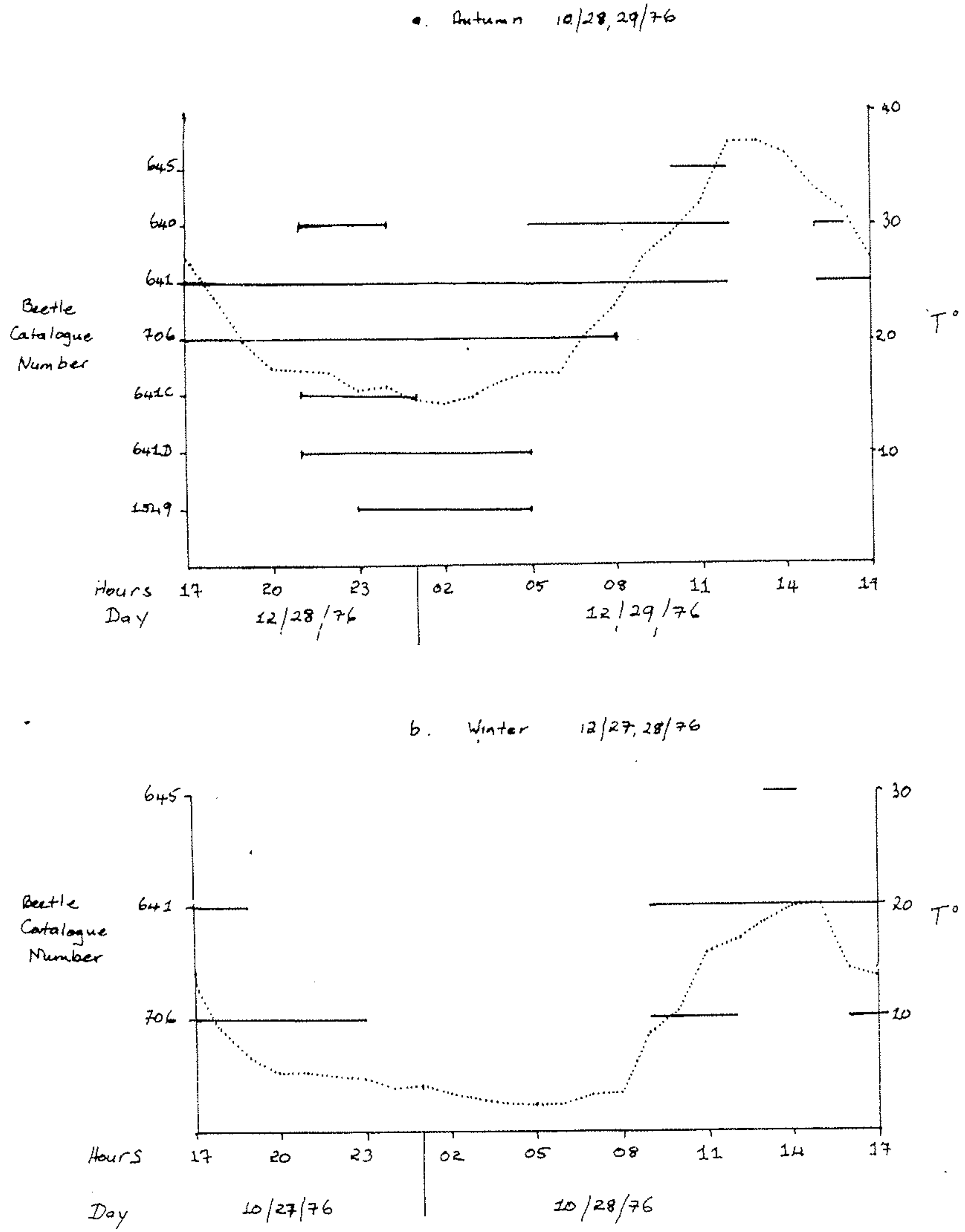


Figure 7.3. Presence of absence activity patterns of large Coleoptera over 24 hour periods in autumn 1976 and winter 1976-77. Ground surface temperatures in the open are shown for the same periods.

Observations revealed a high intensity of Coleopteran activity in autumn and spring with a low intensity in winter. The limited diel activity cycles in each species, as demonstrated in the presence-absence study, were also indicated by the intensity study. In autumn and spring, activity was predominantly nocturnal; but in winter there was a shift toward diurnal activity (Fig. 7.4a,b,c).

Cat. Nos. 641D, 641C and 1549 were strictly nocturnal, Cat. No. 706 was nocturnal in spring and autumn but crepuscular in winter, Cat. No. 641 was nocturnal and crepuscular in spring and autumn but diurnal in winter, and Cat. No. 645 was diurnal. Blaps dominated in intensity in spring and autumn. Cat. No. 641 was the most active in winter, but on an absolute scale, it was not as active as its populations were in spring and autumn (Fig. 7.4a, b, c). Spring shows the highest activity intensity for all species of Coleoptera studied (Fig. 7.4c).

Discussion.-- As with ants, there is a lack of data for summer and part of spring, and firm conclusions on the activity pattern of the large Coleoptera cannot be drawn. However, trends revealed in 1974-75 and 1975-76 studies have generally been supported in the seasons studied.

Activity periods of large Coleoptera show a limited diel cycle. Seasonal changes in activity of large Coleoptera are characterized by a temporal shift from diurnal foraging in winter to nocturnal and crepuscular in other seasons.

The sharp decrease in Blaps activity intensity between autumn and winter supports conclusions drawn from the 1975 autumn activity results (1975 Report). Again the high autumn Blaps activity record was taken only shortly after the first effective autumn rain (24mm) and was followed by the extremely low winter values 2 months later.

Lizard Study

Method.-- Transect studies were conducted with the lizards between autumn 1976 and spring 1977 using the same method as applied to the Coleoptera.

Results and discussion.-- In autumn both Acanthodactylus inornatus and Eremius sp. were active for most of the daytime. The gecko, Sternodactylus, was found only at night. In winter only A. inornatus was active, this being for a few hours at the hottest part of the day. In spring Sternodactylus was again active at night, while A. inornatus and Eremius were active in the daytime as in autumn (Fig. 7.5). Unlike in autumn, A. inornatus tended to be active in the morning and Eremius in the afternoon. This result is atypical when compared with those for 1975 and 1976. Generally the Eremius activity peak is close to the middle

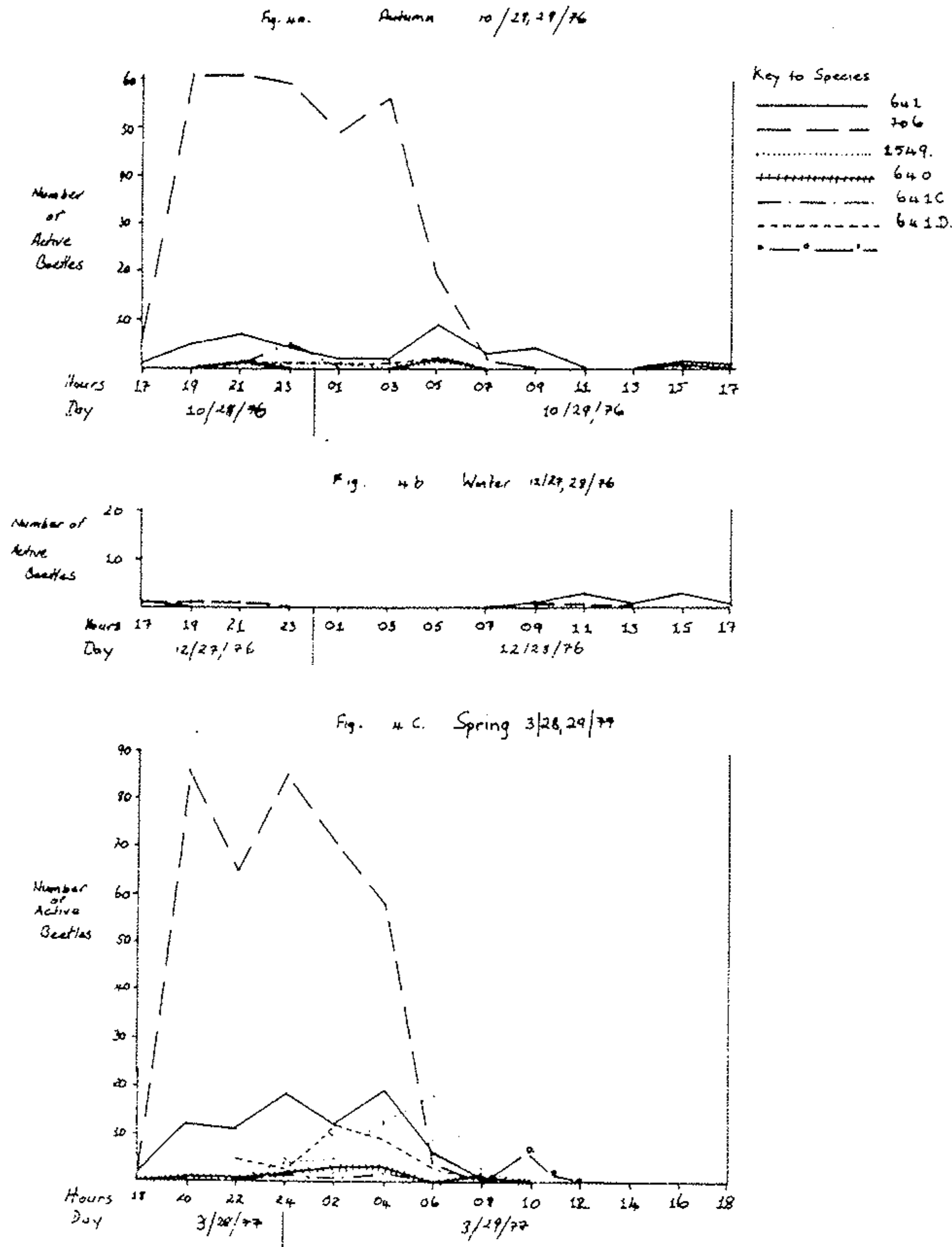


Figure 7.4. Numbers of active individuals of seven species of large Coleoptera observed during transect counts conducted every 2 hours over 24 hour periods in autumn 1976, winter 1976-77 and spring 1977.

Figure 5a. Autumn 10/28, 29/76

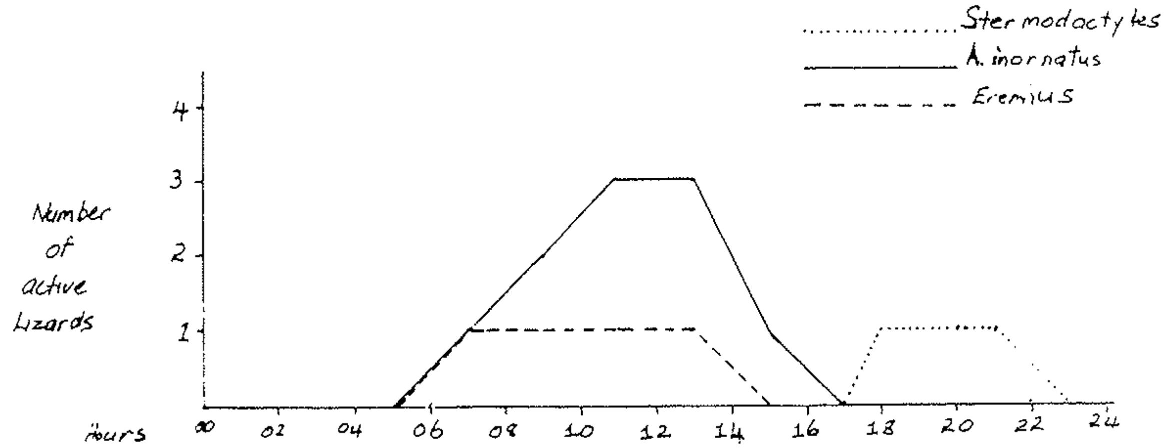


Figure 5b. Winter 12/27-28/76

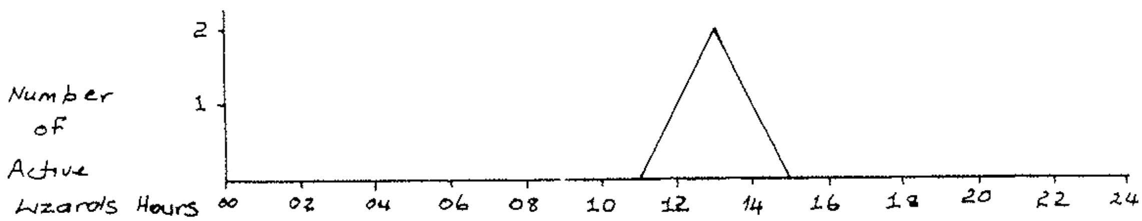


Figure 5c. Spring 3/28, 29/77

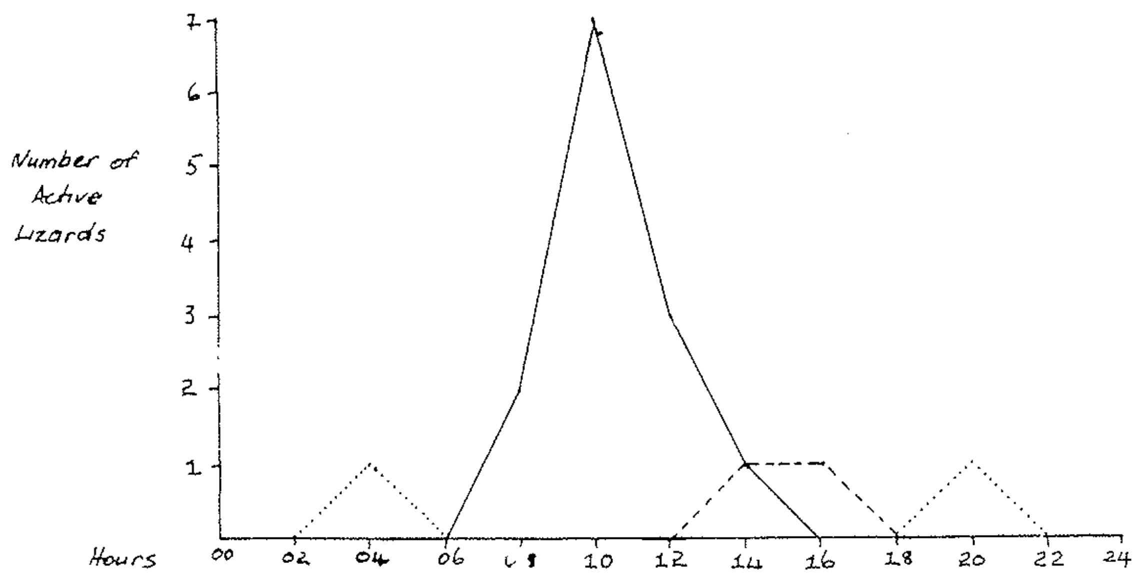


Figure 7.5. Numbers of active lizards observed during transect counts conducted every 2 hours over 24 hour periods in autumn 1976, winter 1976-77 and spring 1977.

of the day and for *A. inornatus* there is usually a second activity peak in the afternoon.

Results still show a limited diel cycle with different foraging times for different species. These are temporal shifts with changes in season thought to be in response to temporal shifts in preferred temperature ranges.

CHAPTER 8

MICROCLIMATE STUDIES

by R.J. Muir and H. Heatwole

Method

The method employed is identical to that employed from 1973-1976 and will not be described again here (See Progress Reports 2 and 3, 1973 and 1974. Thermal microclimate studies were conducted in autumn 1976, winter 1976-77, and spring 1977.

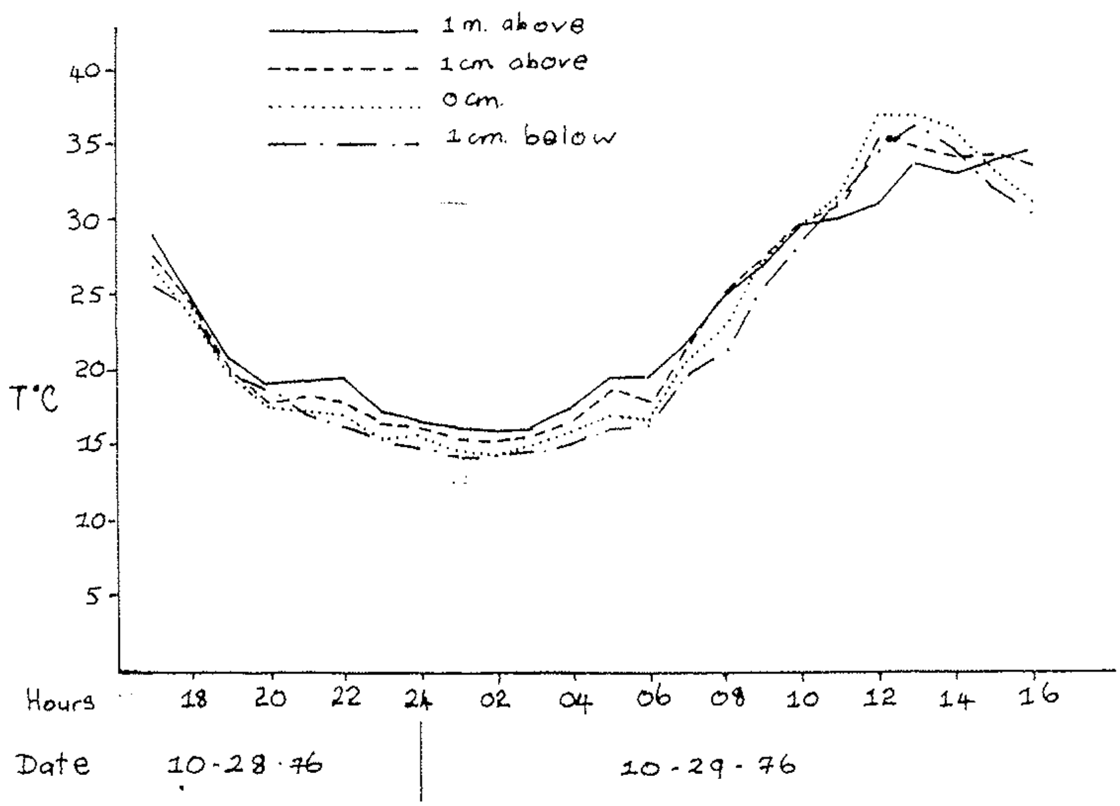
Results

Autumn.-- In autumn, temperature values in the vertical profile ranged from about 14° to 37° C. The range at any one time along the profile was very low (Fig. 8 .1). Air temperature 1 m above the ground surface fluctuated least at the extremes of the diel cycle, while temperatures at the surface and 1 cm below the surface fluctuated most (Fig. 8 .1).

As in previous years, there was a temporal displacement in the maximum diel fluctuation from site to site on the ground surface in relation to nebkas (Fig. 8.2). The eastern site peaked early, followed by the interplant-space site, while the western site peaked later in the afternoon (Fig. 8.2). This effect is due to the microtopography of nebkas in relation to the angle of incidence of solar radiation. Thermal amplitude (the maximum range in temperature between points 1 cm above, at, and 1 cm below, the soil surface at any one time) in autumn may be seen in Fig. 8 .3. Maximum thermal amplitude occurred in the daytime at the maximum diel fluctuation with the three sites separated temporally in maximum amplitude as were absolute values for soil surface.

Prevailing weather conditions influenced thermal microclimate appreciably in autumn. Cloud cover rose at 0300 hours to above 30% and increased to 100% by 0600 hours, when minimum temperatures can normally be expected. Due to the cloud cover, temperature began to rise at o300 hours and only dipped slightly at 0600 hours (Figs. 8 .1 and 8.2). Another factor was the southerly wind which, at the maximum diel fluctuation, suppressed temperature at the relatively exposed open site and reduced thermal amplitude. Maximum fluctuation and thermal amplitude at the relatively protected east and west sites were much higher (Figs. 8.2 and 8.3).

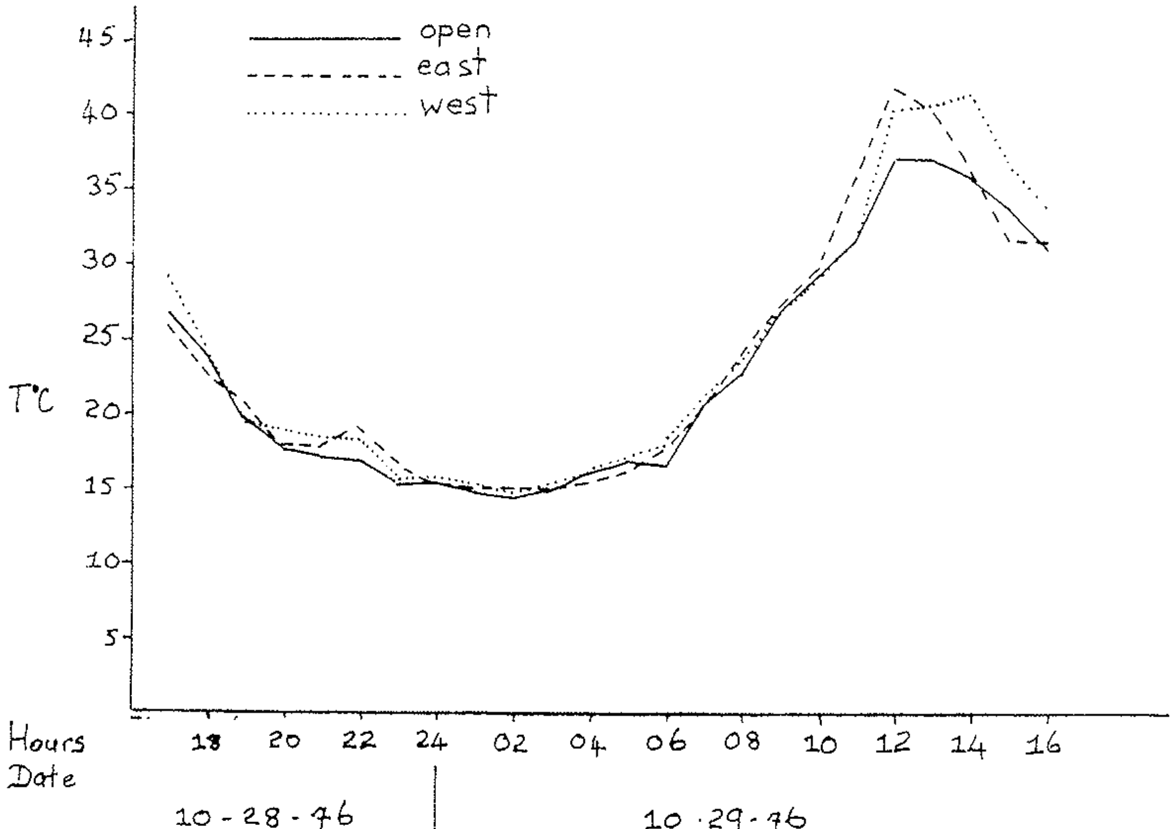
Winter.-- In winter, maximum and minimum temperatures were of course much lower than in autumn, and the temperature range in the vertical profile was lower (Fig. 8 .4). Temporal separation of peaks for the different nebka sites was not pronounced, and it is thought that a mistaken reading at 1500 hours for the open site confused the results (Fig. 8.5).



% cloud cover	5	5	0	0	0	0	0	0	0	0	30	30	90	100	100	100	70	75	50	30	25	20	30	40
wind direction	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind Strength	SB	SB	MB	MB	MB	MB	MB	MB	MB	MB	MB	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	SW	MW	MW

S = strong M = Medium L = Light B = Breeze W = wind

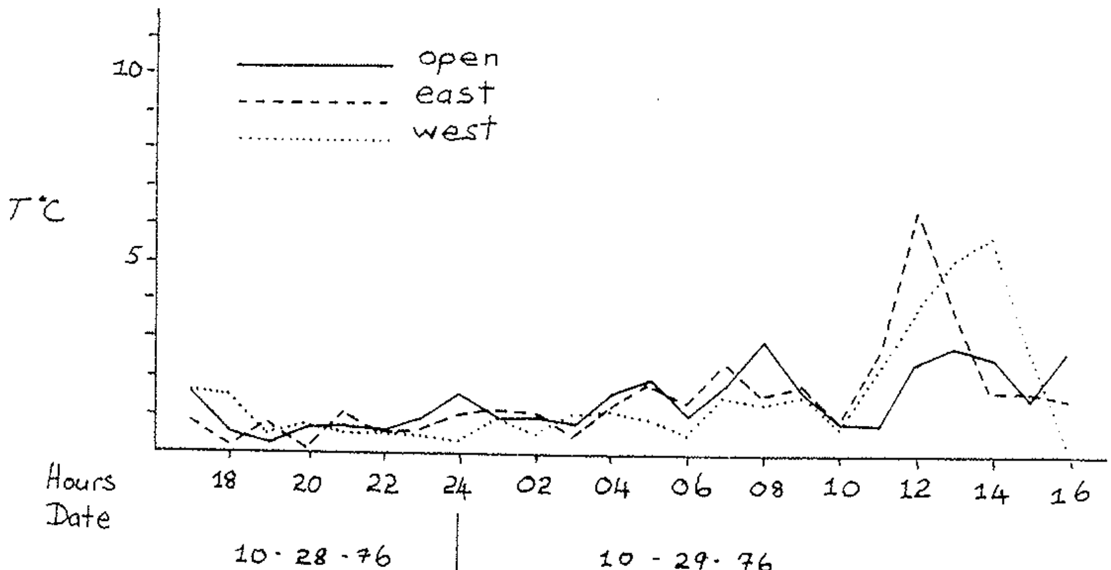
Figure 8.1. Daily change in autumn 1976 temperature in the interplant space at different heights above and below the ground surface.



% cloud cover	5	5	0	0	0	0	0	0	0	0	30	30	90	100	100	100	70	75	50	30	25	20	30	40
wind direction	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind strength	SB	SB	MB	MB	MB	MB	MB	MB	MB	MB	MB	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	SW	MW	MW

S = strong M = medium L = Light B = breeze W = wind

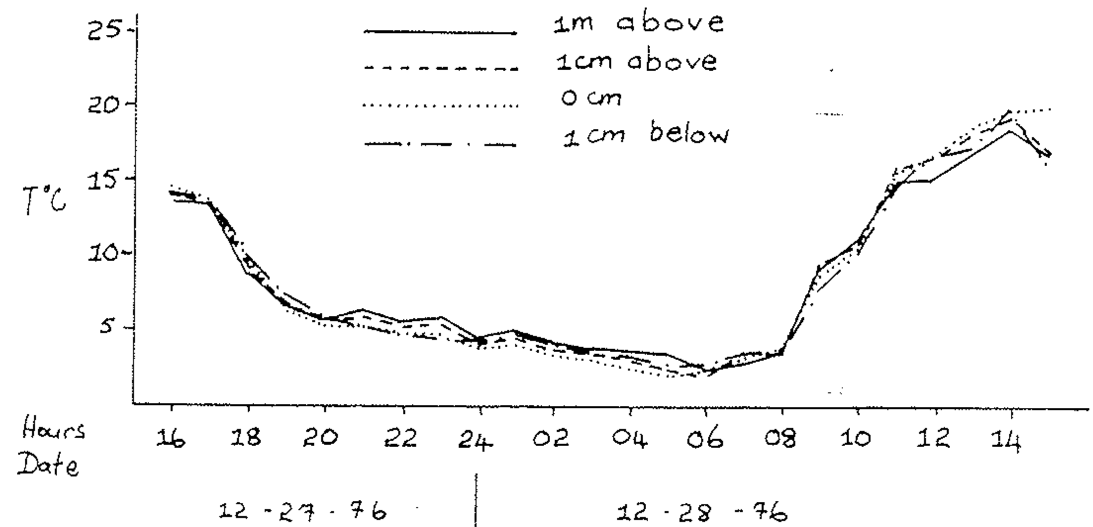
Figure 8.2. Daily change in autumn 1976 soil surface temperature in the interplace space and on the east and west edges of a nebka.



% cloud cover	5	5	0	0	0	0	0	0	0	0	30	30	90	100	100	100	70	75	50	30	25	20	30	40
wind direction	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind Strength	SB	SB	MB	MB	MB	MB	MB	MB	MB	MB	MB	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	SW	MW	MW

S = strong M = Medium L = Light B = Breeze W = wind

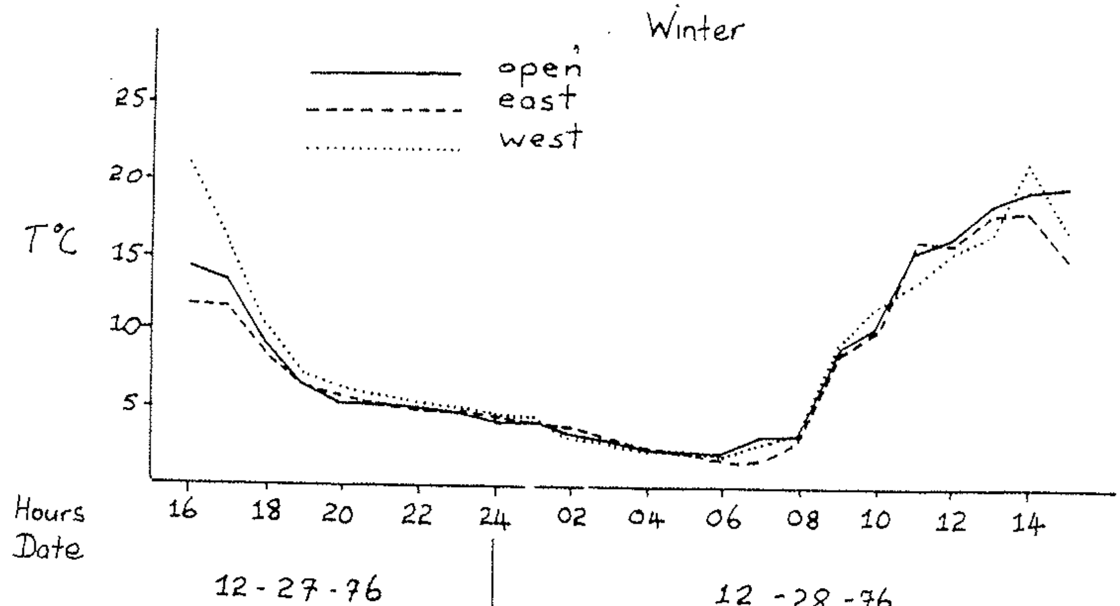
Figure 8.3. Thermal amplitude in audumn 1976 in the interplant space and on the east and west edges of a nebka. (Thermal amplitude is the maximum range in temperature between positions 1 cm above and 1 cm below the ground surface.)



% cloud cover	0	0	0	0	0	0	0	<5	<5	<5	<5	<5	<5	10	20	40	40	60	90	70	70	70	40	70
wind direction			N	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind strength			LB	LB	LB	LB	LB	MB	MB	MB	LB	LB	LB	LB	LB	LB	LB	MB	SB	LW	LW	LW	MW	MW

S = strong   M = medium   L = light   B = breeze   W = wind

Figure 8.4. Daily change in winter 1976-77 temperature in the interplant space at different heights above and below the ground surface.



% cloud cover	0	0	0	0	0	0	0	<5	<5	<5	<5	<5	<5	10	20	40	40	60	90	70	70	70	40	70
wind direction			N	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind Strength			LB	LB	LB	LB	LB	MB	MB	MB	LB	LB	LB	LB	LB	LB	LB	MB	SB	LW	LW	LW	MW	MW

S = strong M = medium L = light B = breeze W = wind

Figure 8.5. Daily change in winter 1976-77 soil surface temperature in the interplant space, and on the east and west edges of a nebka.

Thermal amplitude values were lower in winter than in autumn (Fig. 8.6).

Spring.-- In spring, absolute temperatures were high and there were large ranges along the vertical profile during the day (Fig.8.7). Temperature values 1 m above the ground surface were lower than those at the other sites in the vertical profile for the whole 24 hrs (Fig. 8.7). This is normal for the maximum fluctuation, and it is though that cold northerly winds and breezes at night suppressed minimum temperatures at 1 m , below those at the other three vertical sites.

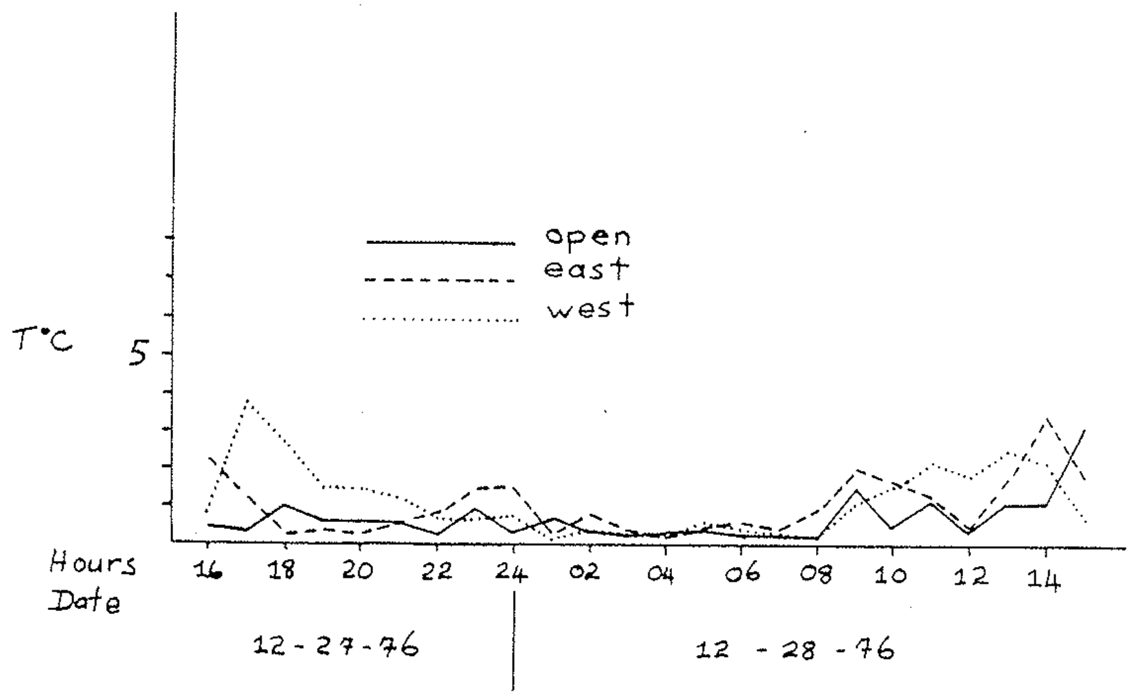
Temporal displacement of maximum temperature fluctuations and maximum thermal amplitude for the three nebka-associated sites was as in autumn (Figs. 8.8 and 8.9). Thermal amplitude in spring was high compared to that in winter and autumn, and was at a maximum in the daytime (Fig. 8.9).

Prevailing weather conditions again influenced results. Cloud cover overnight influenced the maximum diel fluctuation in temperature, and a cloud obscuring the sun at 1400 hrs caused a sharp fluctuation in temperatures (Figs. 8.7 and 8.8).

Discussion.-- Microclimatic data demonstrate the importance of temporal and spatial factors in the thermal environment of an animal. The extremes in temperature, particularly in the hotter months, that any one site experiences over the 24 hr diel cycle poses an accute problem in thermo-regulation for animals in this system. However, spatial variation in thermal conditions, related to microtopography or to a vertical profile, allows animals to change their thermal microenvironment at any time, merely by moving from one locality to another.

For instance, an animal might change its position from one side of the nebka to the other and take advantage of different incidences of solar radiation to select a preferred temerature range. This has been noted particularly with the lizard, Acanthodactylus inornatus which, on a warm day, may extend its foraging duration by seeking warm nebka sites in the cooler parts of the day (east in the early morning and west in late afternoon), and cool nebka sites in the hotter parts of the day (west in late morning, east in early afternoon).

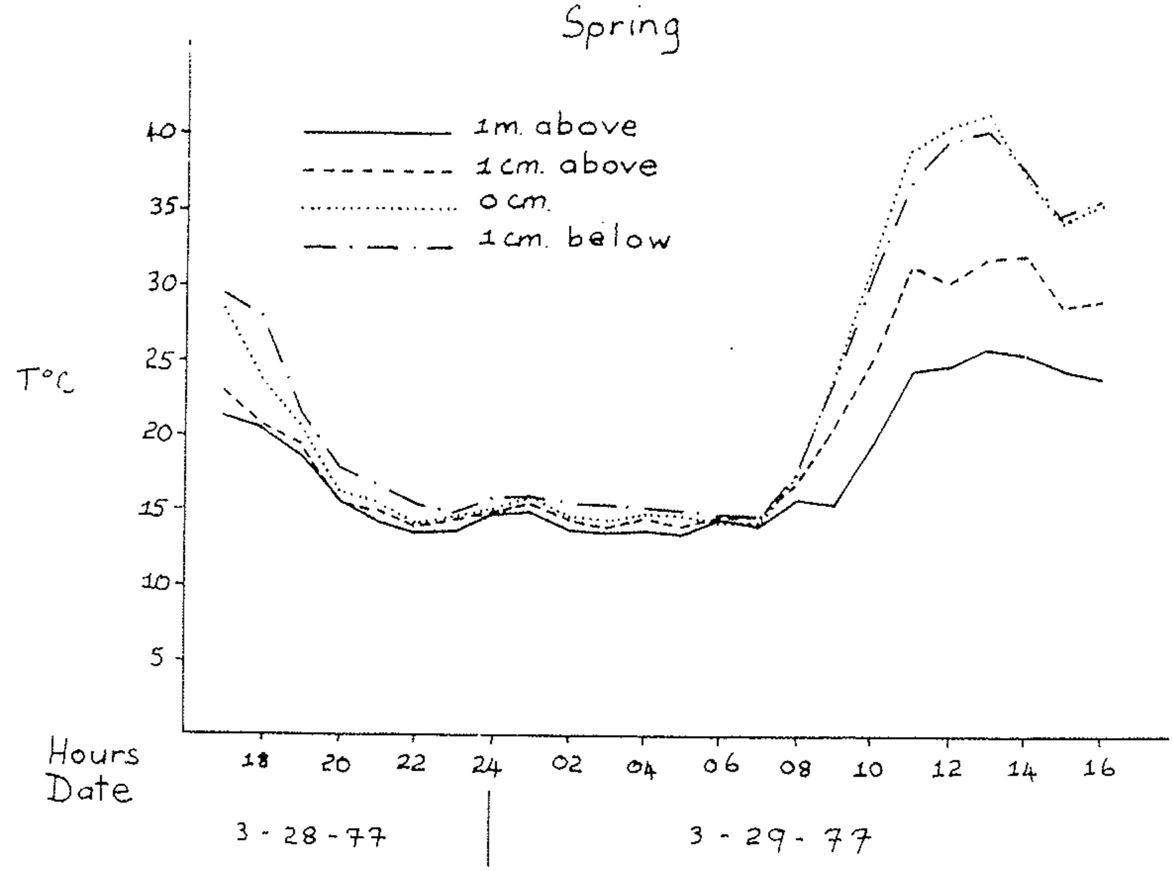
The other possibility revealed by microclimatic data is for an animal to change its position vertically in relation to the soil surface. High thermal amplitudes between positions 1 cm above, at, and 1 cm below the soil surface allow even a very small insect to change its thermal environment considerably by a vertical movement of less than 2 cm. The existence of a rich arthropod fauna in the microhabitat associated with a loose soil surface suggests that this method of thermo-regulation is a common strategy. Over the years of study a considerable number of mites, lygaed nymphs and adults, and Thysanurans have been noted in this microhabitat. Their ability to burrow beneath, or walk on, the soil surface with ease allows them to use a range of temperatures associated with the vertical profile.



% cloud cover	0	0	0	0	0	0	0	<5	<5	<5	<5	<5	<5	10	20	40	40	60	90	70	70	70	40	70
wind direction			N	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
wind strength			LB	LB	LB	LB	LB	MB	MB	MB	MB	LB	LB	LB	LB	LB	LB	MB	SB	LW	LW	LW	MW	MW

S=strong M=medium L=Light B=breeze W=wind

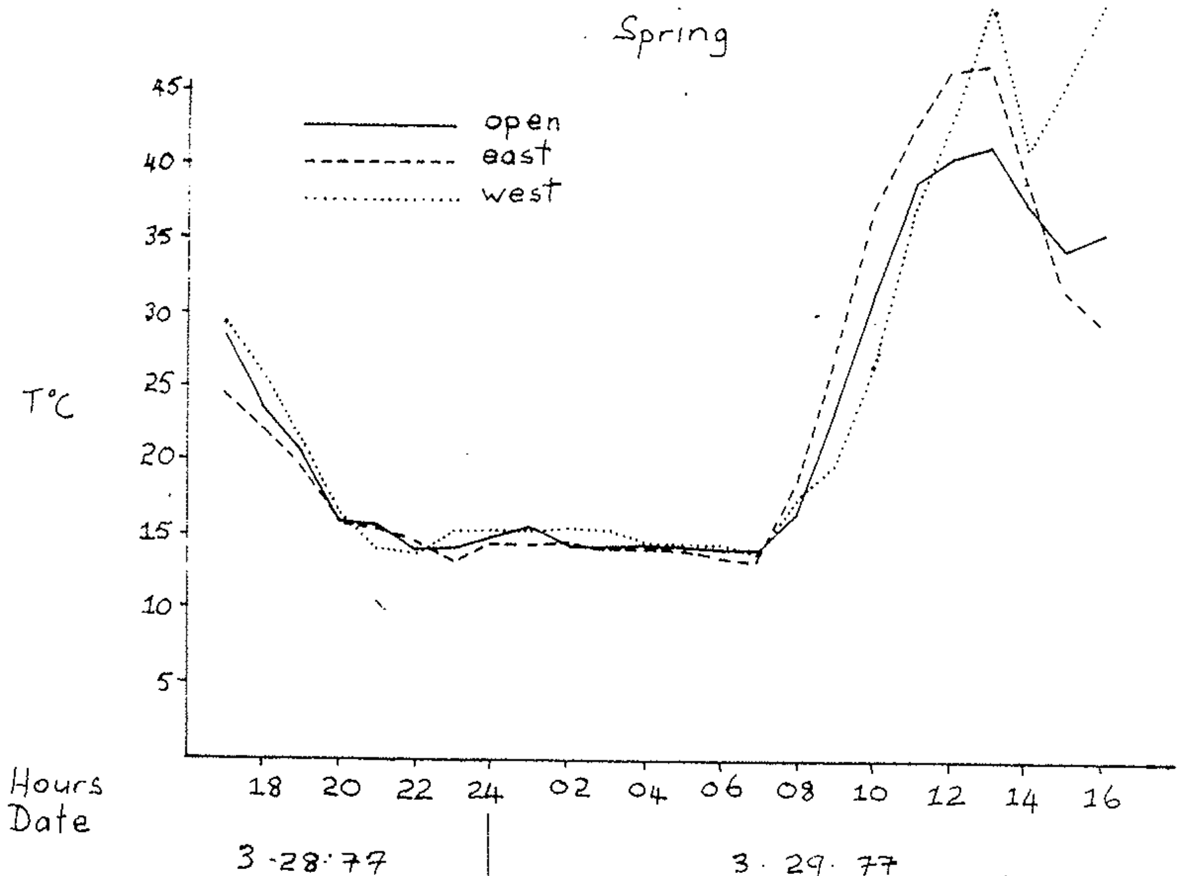
Figure 8.6. Thermal amplitude in winter 1976-77 in the interplant space and on the east and west edges of a nebka.



% cloud cover	98	80	70	30	10	30	90	95	50	100	80	90	98	95	60	70	30	40	20	20	10	85	60	15
wind direction	NE	NE	NE	E	E	N	NE	N	N		N	N-NW	NW	NW	NW	N	N	N	N	N	N	N	N	N
wind strength	LW	LW	LW	MB	MB	LB	MB	MB	MB.		LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	MW

S= Strong M=moderate. L= Light B= breeze W= wind

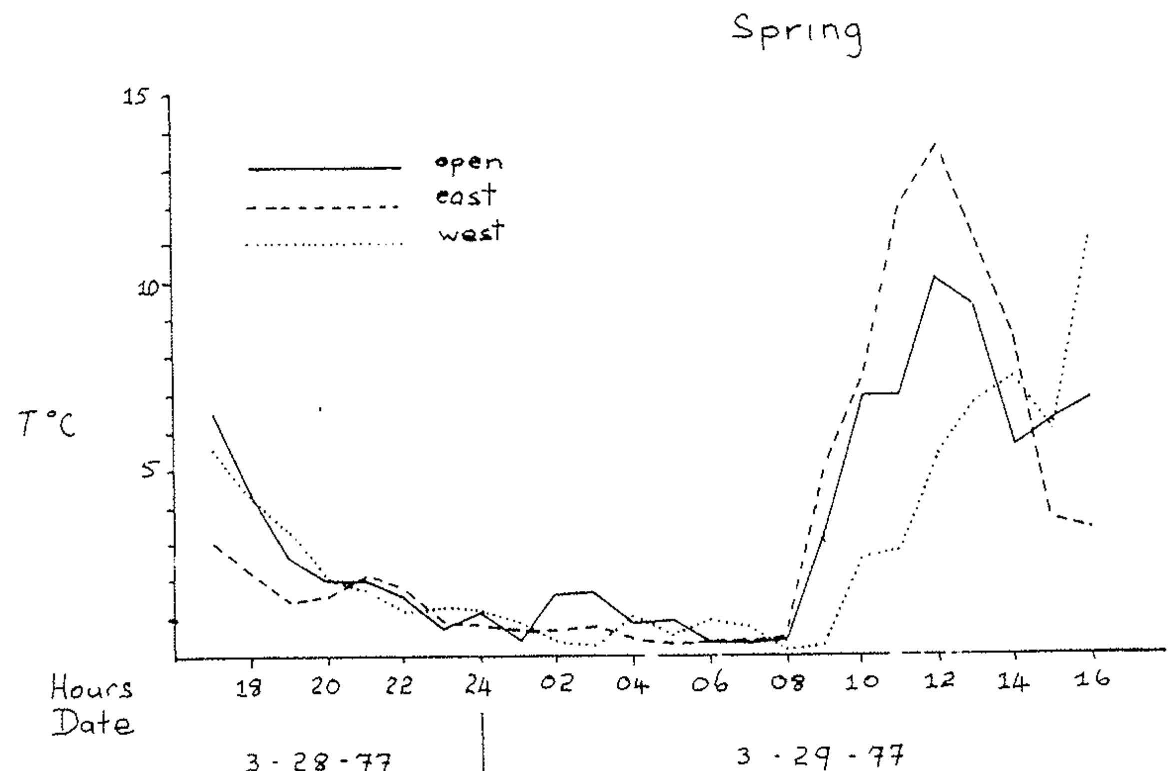
Figure 8.7. Daily change in spring 1977 temperature in the interplant space at different heights above and below the ground surface.



% cloud cover	98	80	70	30	10	30	80	95	80	100	80	90	98	95	60	70	30	40	20	20	10	85	60	15
wind direction	NE	NE	NE	E	E	N	NE	N	N		N	N-NW	NW	NW	NW	N	N	N	N	N	N	N	N	N
wind strength	LW	LW	LW	MB	MB	LB	MB	MB	MB		LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	MW

S= strong M= moderate L= light B= breeze W= wind

Figure 8.8. Daily change in spring 1977 soil surface temperature in the interplant space, and on the east and west edges of a nebka.



% cloud cover	98	80	70	30	10	30	80	95	80	100	90	90	98	95	60	70	30	40	20	20	10	85	60	15
wind direction	NE	NE	NE	E	E	N	NE	N	N		N	N-NW	NW	NW	NW	N	N	N	N	N	N	N	N	N
wind strength	LW	LW	LW	MB	MB	LB	NB	MB	MB		LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	LW	MW	MW

S= Strong M= moderate L= light B= breeze W= wind

Figure 8.9. Thermal amplitude in spring 1977 in the interplant space, and on the east and west edges of a nebka.

CHAPTER 9

INVERTEBRATE TROPHIC STUDIES

by R.J. Muir and H. Heatwhole

Seed Predation by the Harvesting Ants Messor A and Messor B

Workers of active harvesting-ant colonies (Messor A and Messor B) collect fruit and seeds of a variety of annual and perennial herbs and shrubs. In the nest, seeds are removed from the fruits and the left-over ovary wall or seed coverings are discarded on the nest midden. Two methods have been used to measure seed predation. These were described in the 1975 Progress Report and will only be outlined briefly here.

Nest midden analysis.-- Throughout 1975, nest middens were collected weekly for Messor A and Messor B colonies in Areas 1-3, 4, 5 and 6. Middens were first separated into soil and plant material, and the plant material was divided into fruits and other parts of the different plant species. Using plant biomass data on the number and weight of seed per fruit, the dry weight of seed material consumed by the Messor species may be determined. Sorting the middens has been time consuming and is only just nearing completion. Interpretation of results should appear in the 1978 Report.

Daily counts of seed-gathering activity.--

Method: Nests of Messor A and Messor B were observed over their daily activity cycle in autumn 1976, winter 1976-77, spring 1977, and summer 1977. In autumn and winter, observations were conducted in Area 6 and 1-3 only, while in spring and summer Area 7 was included. For 10 to 15 min in every hour the number and type of fruits and seeds collected by workers of each colony were recorded. Using ant population data for the number of active colonies of each species per ha in the three areas, and plant data on the number of seeds per fruit of each species, the rate of seed predation per day per ha was calculated for the harvesting ants (Table 9.1).

Results: To assist in evaluation of results, total seed collection per day per ha was calculated for each ant species at each season in the three areas (Fig. 9.1, Table 9.2). To simplify comparison in terms of types of seeds collected, the main species gathered by the ant species were examined in relation to area and season separately (Tables 9.3 and 9.4).

In general, number of seeds taken in autumn and winter were low in both harvesting ant species in the two areas studied. There was a sharp increase in seed collection in spring for both areas, followed by a reduction to a lower collection rate in summer (Fig. 9.1, Table 9.2). The only exception was the slight rise in seed predation between spring and summer

Table 9.1

Number of Seeds Collected per Day per Hectare by Messor A and Messor B in Areas 1-3 and 6 in Autumn 1976, Winter 1976-77, Spring 1977 and Summer 1977 and in Area 7 in Spring and Summer 1977

	No Seeds x 10^6 per Day per Ha by Season, Area and Ant Species																			
	Autumn				Winter				Spring						Summer					
	1-3		6		1-3		6		1-3		6		7		1-3		6		7	
Plant Species	MA[1]	MB[1]	MA	MB	MA	MB	MA	MB	MA	MB	MA	MB	MA	MB	MA	MB	MA	MB	MA	MB
Atractylis	.001	.019	<.001																	
Daucus	.008	.031	<.001	.005		.016	.001	.011	.001	.031					.001	.050	.002	.018	.001	.089
Salsola	.002	.007	<.001	.004	<.001	.008										.013				
Paronychia	<.001																			
Cutandia	.003	.051			.002	.006		.006		.007				.020	.001	.033		.020	<.001	.033
Hedysarum	<.001	.027			.001	.006	<.001	<.001	.003	.002			.065	.001	.009	.001	.007		.001	
Medicago	.006										.008					.023	.024			
Hordeum	.002															.003	<.001		.001	
Ifloga	<.001														<.001	.006			.001	
Schismus		.026				.006				.016				.031		.033		.009		
Helianthemum					.019		.043		.433	.376				.039						
Argyrolobium								.003	.004	.015	.034	.108		.013				.010		
Artemisia					.019	.026														
Inula					<.001	.006														
Plantago									.194	.034	.107	1.143		.024	.005		.003			
Zollikoteria									.001	.131		.016	.037	.080						
Astragalus										.071					.002	.036				.001
Lotus										.134				.034	.033	.004				.099
Hypocrepis														.010	.006	.014			.002	
Rhanterium														.011		.013				
Asphodelus														.025						
Linaria															.001					
Retama																	<.001			

[1] MA = Messor A, MB = Messor B

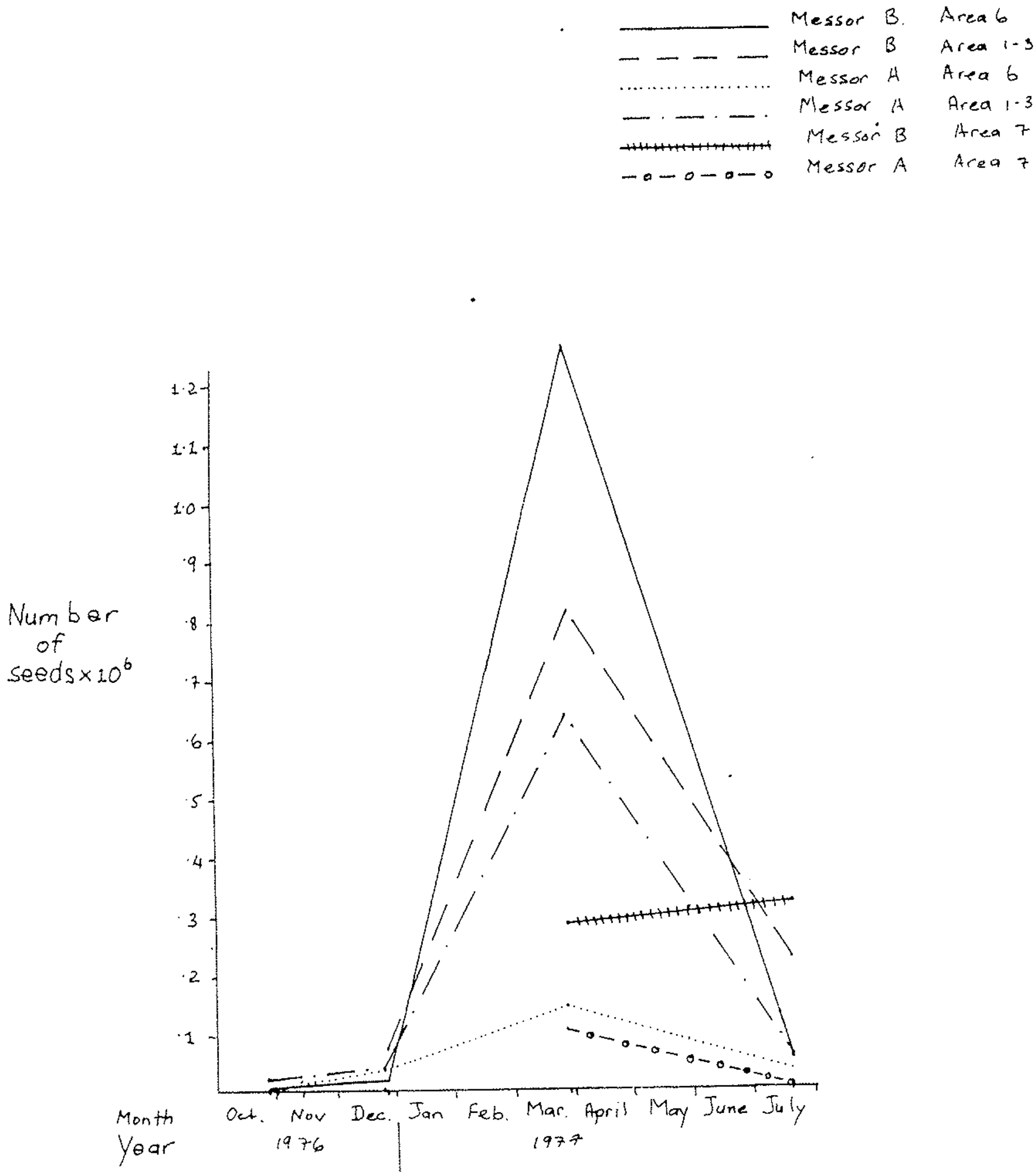


Figure 9.1. Total number of seeds gathered per day per hectare by Messor A and Messor B in autumn and winter 1976-77 in Area 1-3 and 6 and in spring and summer 1977 in Areas 1-3, 6 and 7.

in Area 7 (Fig. 9.1, Table 9.2). Generally, for each ant species, Area 1-3 showed a higher predation rate of seeds than Area 6, and within each area, Messor B showed a higher seed predation rate than Messor A (Fig. 9.1, Table 9.2). There were only two exceptions to the pattern. One was in winter when the Messor A predation rate in Area 6 exceeded both the Messor A rate in Area 1-3 and the Messor B rate in Area 6. The other was in spring, when the Messor B rate in Area 6 exceeded the Messor B rate in Area 1-3 (Fig.9 .1, Table 9.2).

In both Tables 9.3 and 9.4, there is a distinct difference between the types of fruit and seeds gathered by Messor A and Messor B. Messor A gathered the large, multiple-seeded fruit such as Helianthemum, Medicago, and Lotus. Even those single-seeded fruit collected were generally collected in groups as a part of an inflorescence (e.g. Plantago, and Artemisia) (Tables 9.3 and 9.4). In contrast, Messor B generally collected single-seeded fruit, or more often, the single seeds dehisced from fruit. For example, Cutandia, Hedysarum, Schismus, Plantago, Zollikoferia, Lotus, Astragalus and Salsola are all collected by Messor B as single seeds or single-seeded fruit (Tables 9.3 and 9.4). Hedysarum, the only single seed collected extensively by Messor A was still surrounded by pericarp and quite heavy. Messor B, however, collected the seed and discarded the pericarp. The only multiple-seeded fruit collected extensively by Messor B was Helianthemum in spring in Area 1-3. Here the fruits were collected by the largest workers. The intermediate, Daucus (two seeds), was collected extensively by both ant species (Tables 9.3 and 9.4).

Table 9.2

Total Number of Seeds Gathered per Day per Hectare by Messor A and Messor B in Areas 1-3, 6 and 7 between Autumn 1976 and Summer 1977

		Number of Seeds x 10^6 by Season			
Area	Ant Species	Autumn 1976	Winter 1976-77	Spring 1977	Summer 1977
1-3	Messor A	.022	.041	.636	.058
	Messor B	.135	.074	.817	.229
6	Messor A	.001	.044	.149	.036
	Messor B	.009	.020	1.267	.057
7	Messor A			.102	.006
	Messor B			.288	.321

[1] Area 7 was only examined in spring and summer, 1977.

Table 9.3

Main Species of Seeds Gathered by *Messor* A and *Messor* B in Each Season, 1976-77

Ant Species	Plant Species by Season			
	Autumn 1976	Winter 1976-77	Spring 1977	Summer 1977
Messor A	*Daucus* 2[1] *Medicago* M	*Helianthemum* M *Artemisia* M	*Helianthemum* M *Plantago* M *Hedysarum* 1	*Lotus* M *Medicago* M *Hedysarum* 1
Messor B	*Cutandia* 1 *Daucus* 2 *Hedysarum* 1 *Schismus* 1	*Artemisia* 1 *Daucus* 2 *Cutandia* 1 *Salsola* 1	*Plantago* 1 *Helianthemum* M *Zollikoferia* 1 *Lotus* 1	*Daucus* 2 *Lotus* 1 *Astragalus* 1 *Cutandia* 1 *Schismus* 1

[1] Symbol after seed species indicated in what number seeds were collected:
1 = 1-seeded, 2 = 2-seeded, M = multiple-seeded

As in 1975-76, the difference between the seasons in types of fruit and seeds gathered appear to reflect availability (Table 9.3). For example, in autumn 1976, most of the seeds and fruit collected were residual from the growth in spring 1976 (e.g. *Daucus*, *Medicago*, *Hedysarum*, *Schismus* and *Cutandia*). In winter, *Salsola*, (which flowers in late summer), *Artemisia* (autumn), and *Helianthemum* (late autumn and winter) fruits became available, while some residual *Daucus* and *Cutandia* were still collected. In spring, *Helianthemum* was still available in large numbers and *Plantago*, *Zollikoferia* and *Lotus*, which flowered in late winter and early spring, were also collected extensively. In summer *Lotus*, *Medicago*, *Hedysarum*, *Schismus*, *Cutandia*, *Astragalus* and *Daucus* were collected. Some of these became available during spring 1977 growth, but many, particularly *Hedysarum*, *Daucus*, *Schismus* and *Cutandia* were residual from the heavy spring 1976 growth (Table 9.3).

In comparing the different areas for types of food gathered, no striking differences are evident. An effective comparison can be made only between Areas 1-3 and 6 as Area 7 was only studied in spring and summer 1977. Area 1-3 showed a wide range of plant species from which seeds were collected by both ant species. Though seeds of the smaller, lower plants such as *Plantago*, *Cutandia* and *Daucus* were foraged in both Areas, in Area 1-3 more of the taller plants such as *Artemisia*, *Zollikoferia* and *Helianthemum* were foraged for seeds and fruit (Table 9.4).

Table 9.4

Main Species of Seeds Gathered by *Messor* A and *Messor* B in Each Area, 1976-77

Ant Species	Area 1-3		Area 6		Area 7	
	Plant Species by Area					
Messor A	*Helianthemum*	M[1]	*Plantago*	M	*Hedysarum*	1
	Plantago	M	*Helianthemum*	M	*Zollikoferia*	1
	Lotus	M	*Medicago*	M		
	Artemisia	M				
Messor B	*Helianthemum*	M	*Plantago*	1	*Lotus*	1
	Lotus	1	*Argyrolobium*	1	*Astragalus*	1
	Zollikoferia	1	*Daucus*	2	*Daucus*	2
	Daucus	2	*Cutandia*	1	*Zollikoferia*	1
	Astragalus	1			*Cutandia*	1
	Cutandia	1				
	Schismus	1				

[1] Symbol after seed species indicates in what number seeds were collected: 1 = 1-seeded, 2 = 2-seeded, M = multiple-seeded

Discussion: The higher rate of seed gathering of *Messor* B compared to *Messor* A, is probably related to the relative density of the two species. In active colony numbers alone, *Messor* B exceeds *Messor* A in all areas at all seasons. In numbers of individuals per colony, *Messor* B exceeds *Messor* A by a factor of about nine. Although *Messor* A can increase its seed predation by gathering multiple-seeded fruit, the marked numerical superiority of *Messor* B probably accounts for its greater seed-collection rate.

The grazing of livestock in Area 6 probably accounts for the lower rate of seed predation in this area, as competition from sheep and goats eating flowers and seed-bearing foliage, would reduce availability for the ants, particularly in those plants favored by the animals.

The greatly increased seed predation in spring is best accounted for by the high availability of seeds from annual plants produced during the spring growing season. Unlike in 1976, the availability of seeds from the annuals did not continue into summer. The 1976-77 precipitation season was very poor (68.6mm), compared to that in 1975-76 (497mm), and thus the spring growth of annuals was short lived and did not continue into summer as in 1976. The increased seed predation in spring might also be explained by increased activity in spring due to advantageous physical conditions for foraging and/or internal demands of producing, maintaining and maturing pre-adult broods present in spring.

The propensity of Messor A to collect large multiple-seeded fruit and Messor B to collect single-seeded fruit or single seeds from larger fruit, is adequately explained by differences in worker size between the two species (mean worker weight of Messor B, 0.99 mg, Messor A, 6.64 mg). Thus the chief factor separating the trophic niches of the harvesting ants, evidently, is the difference in worker size which effectively partitions food supplies between the two species and minimizes potential competition. Messor A would appear to be at an advantage with the multiple-seeded fruit from which both ant species take seeds. Messor A can take the fruit directly from the plant, whereas Messor B must wait until the fruits have dehisced before they can commence to collect them. Thus Messor A probably reduces seed availability for Messor B in these fruits. However, once the fruits have dehisced, the smaller Messor B would be at an advantage in collecting the single seeds more efficiently than Messor A in terms of relative energy expenditure.

As indicated in the results, different seed types gathered in the different seasons can be explained by different life cycles of their respective plants, and the availability of these seeds in residual supplies after all seed production has ceased. Apparently, residual supplies of Hedysarum, Daucus, Cutandia and Schismus from extremely favorable 1976 spring production season are still being collected by the harvesting ants in summer 1977.

Tenebrionid Trophic Studies

In spring, 1976, a study was begun on the feeding habits of the large Tenebrionid beetles and their impact on the PreSaharan vegetation. The three most common species, Blaps (Cat. No. 706), Pimelia obsoleta (Cat. No. 641), and Pimelia sp. (Cat. No. 641B) were examined in the study. Results for spring 1976 and summer 1976 may be seen in the 1976 Progress Report (No. 5). This account includes only autumn and winter 1976-77 results subsequent to the 1976 Report. The method has been described in the 1976 Report and will thus only be briefly outlined here.

Method.-- A "bite count" technique was applied to study the feeding behavior of individual beetles observed in the field. Anything eaten was recorded as to its species and type, i.e. leaf, stem, flower, etc., and replicates of plant parts eaten were collected and stored. At the same time, duration of eating behavior was recorded along with total duration before a different food type was begun. In the laboratory, food replicates were oven dried and weighed. Feeding duration records and stored replicates were grouped for beetle species and plant species. From replicate dry weights and duration records, the rate of consumption of plant species per ha by an active individual of each beetle species was calculated. The percentage of total activity time spent on each plant species was calculated for each beetle species. Data for Tenebrionid activity, taken from the transect study, were used to estimate consumption of vegetation per ha per day. Due to very low numbers of beetles present in late autumn and winter, data for these seasons were combined and the activity results for the transect study 12/27-28/76 were used to calculate vegetation ingestion rates.

Results.-- Generally, the Coleopteran species ingested vegetative parts of plants and bird feces. Sometimes flowers and fruit were ingested but generally this was limited to the floral perianth parts and pericarp. Seeds were not usually eaten. Pimelia showed a preference for green and withering plant material, while Blaps ingested mostly dead plant material, often in the form of small particles and debris.

The larger Pimelia obsoleta had the highest ingestion rate per individual for the late autumn-winter period (0.007 g/ha), while Blaps was lower with 0.004 g/ha. Pimelia obsoleta also exceeded Blaps in total ingestion per day per hectare (Table 9.5). Both Tenebrionid species ingested a variety of plant species. Plantago leaves were ingested in the largest quantities by both Pimelia and Blaps. After Plantago, Pimelia ingested bird feces and Zollikoferia, while Blaps ingested Retama flowers in descending order of preference. Generally annual species made up the majority of the diet, but perennials, such as Rhanterium, Salsola, Pituranthos and Retama were ingested, usually as floral parts or rotting detritus (Table 9.5).

Discussion.-- The above ingestion rates and total ingestion estimates shown in Table 9.5 must be treated with caution as there are many possible sources of error in the method and in dealing with small animals. Possible sample bias, duration bias, replicating errors etc., might all influence results (see Report No. 5 for more details).

In comparison with results taken in spring and summer 1976, the following may be noted in the autumn results:

(1) Ingestion rates per ha were far lower in the late autumn and winter sample than in the spring or summer samples (.004 g/hr per beetle for Blaps in autumn-winter against .039 g/hr and .070 g/hr in spring and summer respectively; .007 g/hr per beetle for Pimelia in autumn-winter against .109 g/hr in spring and summer respectively).

(2) Total dry weight of vegetation and other materials ingested per day per ha was far lower in autumn-winter than in spring and summer. (.3 g/day/ha for Blaps in autumn-winter against 110.1 g/day/ha and 458.2 g/day/ha for spring and summer respectively; and .8g/day/ha for Pimelia against 102.82 g/day/ha and 51.65 g/day/ha for spring and summer, respectively).

(3) A higher proportion of the diet of Pimelia in autumn-winter is animal feces (39% against 14.7% and 1.5% in spring and summer, respectively).

Table 9 .5

Food Type and Ingestion Estimates for Pimelia obsoleta and Blaps sp. (Tenebrionidae) in Autumn and Winter, 1976-77

Plant Species	Blaps sp. (Cat. No. 706) A[1]	B[2]	C[3]	D[4]	Pimelia obsoleta (Cat. No. 641) A	B	C	D
Plantago	38.3	.0065	23.9	.155	28.0	.0098	31.5	.309
Zollikoferia					20.5	.0061	23.1	.141
Bird faeces					8.7	.0302	9.8	.296
Medicago	8.5	.0005	5.3	.003	2.5	.0006	2.8	.002
Linaria					1.7	.0004	1.9	.001
Rhanterium					1.0	.0014	1.1	.002
Ifloga					4.0	.0016	4.5	.007
Schismus					1.5	.0003	1.7	.001
Daucus	4.3	.0004	2.7	.001	1.0	.0017	1.1	.002
Retama	19.1	.0078	11.9	.093				
Unidentified Debris	19.1	.0005	11.9	.006	5.6	.0002	6.3	.001
Salsola					4.3	.0032	4.8	.015
Messor B					0.1	.0001	0.1	<< .001
Predator faeces					3.9	.0005	4.4	.002
Rodent faeces					1.7	.0071	1.9	.014
Hedysarum					3.1	.0009	3.5	.003
Lotus					0.4	.0016	0.5	.001
Pituranthos	10.7	.0015	6.7	.010				
Vacuuming soil					2.5		2.8	0
Argyrolobium					2.9	.0001	3.3	< .001
Nothing Ingested					6.6		7.4	0
Totals			62.4	.268			112.5	.797

[1]A = Percentage activity time associated with plant species

[2]B = Dry weight ingested per hr per individual (grams)

[3]C = Number active beetle-hours per day per ha

[4]D = Total dry weight ingested per day per ha (grams)

The greatly reduced ingestion rate per hr per individual was probably due mainly to lower food requirements in the cooler late autumn and winter weather. Another factor might be the seasonal low availability of food compounded by poor autumn rainfalls.

The very low total dry weight ingested per day per ha in late autumn-winter compared with summer and spring values is partly due to the lower ingestion rate per hr per individual discussed above, but also largely due to the very low numbers of active beetles present in the late autumn-winter season.

Increased proportion of animal feces in the diet of Pimelia obsoleta might be due to the low availability of vegetative foods.

Trophic Studies in Important Transient Species

In spring and summer 1976, as shown in the 1976 Progress Report (No. 5), transient species were numerous and played a significant role in the consumption of vegetation, particularly of some annual species (Zollikoferia). Following the low rainfall season of 1976-77, transient species appeared in such low numbers as to have little influence on the plant species through trophic behavior (see Biomass Section). Thus no trophic studies were conducted for transient species in 1977.

CHAPTER 10

DIETARY COMPOSITION AND PREFERENCES OF SHEEP AND GOATS

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Introduction

In this chapter we analyze the preferences of sheep and goats for the plants found in the pastures of the Tunisian PreSaharan Project. Preference indices indicate relative intensities of use of the various plant species. In general, but far from always, there is an inverse correlation between preference for a plant species and its abundance in the vegetation. Also, when offered highly palatable forage an animal tends to eat more so grows faster than when offered forage of low palatability. Thus preference indices can help in understanding the vegetational responses to grazing by sheep and goats, and the responses in livestock productivity to the availability of various categories of vegetation.

Methods

Observations of forage selection.-- We visually observed the feeding of sheep and goats during eight different analytical periods between 19 August 1976 and 9 April 1977. We only observed lambs and kids if they were at least 1 month old. Lambs and kids were reclassified as adults in September, when they were about 9 months old. Of the adults, we only observed females because they comprised 93 percent of the local adult population of sheep and goats.

During any analytical period, each individual was subsampled for 1 minute of feeding time, then each animal was again observed for 1 minute of feeding time, and so on until each individual animal had been subsampled between 5 and 13 times, depending on the period. In this manner, the first subsample for each individual was taken in the same approximate location as that of every other animal. Similarly, the other subsamples also corresponded. We thereby reduced the variation between individuals that was due to location of feeding.

The animal chosen for subsampling was the one closest to the observer which had not been watched for the subsampling set in progress. At times we altered this random selection process in order to sample more evenly between the ewes, lambs, does, and kids, because each group tended to feed together. For example, if we had sampled few lambs relative to the other groups we would move among the lambs until a similar proportion of them had been subsampled. This system reduced the variation between groups that was due to location of feeding and time of day.

In the analysis of any analytic period, all subsamples for a given individual were combined. The percentages of all the bites taken by that individual from each forage category were computed. The percentage of bites on any forage category by an individual was one experimental unit for that forage category. The experimental units were used to calculate the mean, standard deviation, and confidence interval of each food category for each animal group. In this report the means of two groups are considered significantly different if the probability of their being the same is less than five chances in 100.

We also calculated the approximate percentages of the diets by dry weight for each category. We plucked representative "bites" from each plant species. The weights of dried "bites" were then combined with the mean percentages of bites in order to calculate mean percentages of diets by weight.

Availability measurement.-- Shortly before we observed the diets, 2 m x 10 m plots were harvested of the vegetation produced since the first rain of the previous fall in order to measure availability. Thus vegetation harvested in October had grown during the preceding 12 months, but vegetation harvested in mid-December had grown over the preceding 10 weeks. Being recent growth, the harvested vegetation included little wood. Later we calculated the mean percentage of the total dry weight available which was contributed by each forage category.

We only took dietary observations the first time the flock grazed the vicinity of a harvested plot, because during subsequent grazing the assortments of forage available were different from those that had been harvested. The preference index for any forage category equaled the percentage of diet by weight composed of the forage category, divided by the percentage of the available new growth composed of the category.

We considered each plant species as a different dietary category. We also combined species into group categories according to the life-form classification most recommended by Daubenmire (Plant Communities, Harper and Row, New York, p. 64 of 300 p., 1968), namely the major categories of Raunkiaer. Furthermore, if the material ingested in a bite was mostly green, we categorized it by species and life-form; however, if the material ingested with a bite was mostly brown, we called it either standing dead or litter.

Especially during summer, part of the bites on some species were green and so fell into the category of the species, while other bites on the species were brown and so were placed with the standing dead or litter categories. The plants harvested for the availability estimate were not separated in this manner; rather any species was classified as either all living or all gesh (a local term which combines standing dead and litter). We feel that the method used in the bite counts was more precise. For example, with the arrival of the fall rains green gesh of *Plantago albicans* again became succulent and resumed growth, while brown gesh of the species of course remained brown. During summer and fall, animals ingested much green, apparently living, vegetation from species called gesh in the biomass work. By using our system we derived more exact estimates of the proportions of living and dead materials ingested.

The dietary analyses could still be compared with most aspects of the availability analyses, even though some green phytomass was classified as gesh. All green gesh came from just a few species of hemicryptophytes and therophytes; hence only these species sometimes lacked availability estimates. Amounts of standing dead and litter were not much changed, because the green gesh was always a very small portion of the gesh.

Preference indices for small-sized species during Analytical Periods A and End B (see Table 10.1 for code) could not be determined, because small plants were not harvested even though they were frequently ingested. During Period Begin B, annuals were not harvested by species.

Sample sizes.-- Table 10.1 gives the dates of the analytical periods. It also gives, for each period, the numbers of individual animals (experimental units) observed, the number of subsamples per individual, and the number of vegetational plots harvested. The number of animals in a group varied from 10 to 44, and included all the animals of that type present in the pasture. More subsamples per individual were taken during the three spring pasture periods (C1, C2, and C3) because fewer individuals of each animal type were present in each pasture.

We wish to compare our methods with those of Griego (Chapter 11 of Progress Report No. 4 (1975) and his unpublished Utah State University Master's Thesis), because we will be citing Griego's work throughout this chapter. Weekly for 4 weeks during late April and May 1974, Griego sampled without replacement two rams and two bucks in pasutre C1, and sampled with replacement four rams in C2 and four bucks in C3. We sampled without replacement numerous (see Table 10.1) ewes, lambs, does, and kids, but no rams and bucks through this same period in 1977. Furthermore, we subsampled each experimental unit several times, but Griego observed each of his experimental units only once, for 30 minutes. We counted each animal as only one experimental unit, no matter how many times we subsampled it, while Griego counted each animal as a new experimental unit each time it was sampled, for an average of four experimental units per individual animal.

Bit sizes.-- Table 10.2 shows the estimated dry weights of the bites of each plant species during the different analytical periods. The sizes of bites on preferred plants tended to be larger when more biomass per plant was present. Thus bites on Zollikoferia resedifolia and Argyrolobium uniflorum were larger when animals first entered a pasture, but were smaller at the end of a pasture period after most of each individual plant had been eaten. During the fall (Pasture A) when these two highly palatable species were just beginning to grow, the plants, and thus bites taken from them, were also small. On the other hand, bites on low preference plants tended to become larger after most preferred forage had been consumed,

Table 10.1

Sample Sizes Obtained in Forage Preference Studies, 19 August 1976 to 9 April 1977

Sex-age Class	No. Individuals by Analytical Period and Observation Date							
	Begin D2[1] Sept. 19-23	End D2 Sept. 23-27	All of A Sept. 19-Nov. 11	Begin B Dec. 15-19	End B Feb. 2-8	Begin C1 Mar. 20-27	Begin C2 Apr. 7-8	Begin C3 Apr. 3-9
Ewes	30	43	41	40	33	11	20	0
Lambs	15	0	0	0	14	11	19	0
Does	30	43	44	43	35	11	0	22
Kids	13	0	0	0	18	10	0	24
Subsamples/individual	5 or 6	6	8	5	5	13	8	9
Dates of availability observations	Aug. 13-18	Sept. 22-24	Oct. 19-Nov. 11	Dec. 15-18	Feb. 2-10	Mar. 19-25	Apr. 6-7	Apr. 1-5
No. 2 x 10 m plots harvested	20	10	24	14	36	54[2]	19[3]	46[4]

1 See chapter on stocking rates for letter code representing pastures.

2 Only 24 of these plots were clipped for *Artemisia campestris*, *Rhanterium suaveolens*, *Salsola vermiculata*, and the annuals.

3 Only 13 of these plots were clipped for *A. campestris*, *R. suaveolens*, *S. vermiculata*, and the annuals.

4 Only 20 of these plots were clipped for *A. campestris*, *R. suaveolens*, *S. vermiculata* and the annuals.

Table 10.2

Estimated Dry Weights of Bites by Sheep and Goats

Plant Species	Bite Weight in Mg. by Analytical Period and Sex-age Class									
	Begin D2 Ad.♀ & Yg.	End D2 Ad.♀	All of A Ad.♀	Begin B Ad.♀	End B Ad.♀	End B Young	Begin C1 Ad.♀	Begin C1 Young	Begin C2,3 Ad.♀	Begin C2,3 Young
Nanophanerophytes:										
Aristida pungens			70					20		
Artemisia campestris	40	24	24	38	29	4	22	12	64	64
Echiochilon fruticosum	40	25	75	32	30		90	35	104	25
Polygonum equisetiforme			35	40	226	76	110	50	130	50
Retama raetam	105	57	230				194	102		
Rhanterium suaveolens	90	43	75	49	94	17	170	84	334	100
Salsola vermiculata	51	31	23	73	30	5	107	47	200	54
Chamaephytes										
Anabasis oropediorum	100			120		65				
Argyrolobium uniflorum	159	29	60	100	30	16	127	45	162	89
Artemisia herba alba				14	26	11			155	33
Citrullus colocynthis	100									
Erodium glaucophyllum	121	15	10				239	87		
Fagonia glutinosa			20	72					325	169
Gymnocarpus decander				56	55	16	52		90	40
Haloxylon tamariciföliam						65			130	50
Helianthemum lipii	90	24	28	52	39	10	120	29	150	60
Linaria aegyptiaca	60	33	38	50	82	29	90	33	135	53
Nolletia chrysocomoides	130	8	26	70	56	10	128	28	150	40
Pituranthos tortuosus		30	49	55	50	14	36	33	91	49
Hemicryptophytes										
Astragalus gyzensis	90		10	25	14	14			200	100
Atractylis spp.	200		5	15	19	15	51	26	60	50
Plantago albicans	134		26	51	21	21	82	45	203	102
Zollikoferia resedifolia	105		5	190	10	10	99	34	110	40
Geophytes										
Lygaeum spartum			70	30	363	34				50
Stipa fontanesii	300	26		115	164		148	31	170	

Table 10.2 Cont.

Estimated Dry Weights of Bites of Sheep and Goats Cont.

Plant Species	Begin D2 Ad. ♀ & Yg.	End D2 Ad.♀	All of A Ad.♀	Begin B Ad.♀	End B Ad.♀	End B Young	Begin C1 Ad.♀	Begin C1 Young	Begin C2,3 Ad.♀	Begin C2,3 Young
	Bite Weight in Mg. by Analytical Period and Sex-age Class									
Therophytes										
Asphodelus refructus							92	60	80	62
Bupleurum lancifolium									22	22
Cutandia divaricata			4	9			108	65	30	30
Daucus syrticus			5	9			61	46	40	30
Diplotaxis spp.			5	15			63	50		
Echinopsilon muricatus	62						115	85	100	
Hedysarum spinosissimum			5	12			126	45	80	45
Hordeum murinum			18	30			53	31	35	27
Iflogo spicata				10						
Lotus pusillus	40			.			38	21	30	20
Malva aegyptiaca				10			55	53	50	50
Matthiola longipetala	19		5	15			105	62	95	80
Medicago littoralis							60	46	46	46
Reseda alba				18			214	91	100	90
Schismus barbatus			4	9			70	67	30	30
Senecio delphinifolius							114	54	85	50
ALL ANNUALS MIXED TOGETHER AT					14	14				
Standing Dead	51	65	60							
Litter	295	122	170	50	82	50	290	243		

inducing animals to intensify their feeding on low preference species -- for example, Lygaeum spartum at the end of the Pasture B period. Some plants, such as many of the annuals, were always taken in small bites because the plants were so small.

Results

Nanophanerophytes.-- These plants are shrubs (or in one case a grass) 0.25 to 2.0 m tall.

Aristida pungens contributed less than 1 percent of the biomass available in every pasture except A, where it amounted to 24 percent of the total availability. It had lower preference indices than any other species -- never rating higher than 0.01.

Artemisia campestris (Table 10.3) contributed an average of 26 percent (range 7 to 70 percent) of the new growth in the eight analytical periods. It apparently had the next-to-lowest preference of the species studied, though the status was shared with Artemisia herba alba. Preference indices for A. campestris ranged from 0.00 to 0.17. Griego also concluded that the intake per unit of availability for A. campestris was very low relative to other plant species.

In contrast, Novikoff (Section 2.6 of Progress Report No. 5) concluded that A. campestris was more heavily utilized than any other species, for the treatments in which utilization of A. campestris was analyzed. He obtained his figures from pairs of caged-uncaged plots (ungrazed-grazed plots). We suspect that his results may have been due to experimental artifacts. The caged plots probably produced abnormal amounts of A. campestris owing to microclimatic conditions (Daubenmire, Ecology 21: 514-515, 1940). Furthermore, a plot adjacent to the caged plot was harvested before the cage was set out, which left more soil water for plants in the caged plot, especially for long-rooted plants. Additionally, little of the use of the "grazed" plot appears to us to have been grazing. When a cage was set out, workers trampled the adjacent "grazed" plot considerably. While the flock was grazing, the herders moved from exclosure to exclosure, so that they could lean against the fencing and also prevent animals from climbing over or crawling under the fencing. The herders kept the animals out of the caged plots by striking the ground with their staffs and feet. Of course, this activity considerably trampled the uncaged "grazed" plot, and also prevented the animals from grazing the "grazed" plot to any extent. Most livestock use of the "grazed" plots happened at one time-- during the noontime rests when the animals were not feeding, they were bedded down near or against a cage in order to reduce their movements. Uncaged "grazed" plots received one other type of use -- herders sometimes pulled shrubs from them and used the shrubs to fill gaps along the bases of the cages. In summary, it appears to us that the ungrazed caged plots probably produced abnormal amounts of forage, while the "grazed" uncaged plots were used in many ways but were only slightly grazed.

Table 10 .3

Preference for Artemisia campestris, a Namerophyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	Tr ± 0.2 (0.1)	0.1 ± 0.3 (0.1)	0.7 ± 2.2 (0.7)	0.5 ± 1.2 (0.4)	15.8 ± 12.9 (3.8)	0.3 ± 0.8 (0.4)	0.8 ± 1.6 (0.5)	
Goats: only does unless kid rate stated below	1.0 ± 3.2 (1.0)	2.9* ± 4.7 (1.4)	1.4 ± 2.5 (0.8)	0.6 ± 1.3 (0.4)	18.6 ± 12.2 (3.4)	0.3 ± 0.7 (0.3)		1.6 ± 3.1 (0.09)
Ewes: amount is under sheep if no lambs observed	0				15.5 ± 12.4 (4.4)	0.1 ± 0.2 (0.2)	0.6 ± 0.2 (0.2)	± 1.3 (0.6)
Lambs:	0.1 ± 0.4 (0.2)				16.6 ± 14.6 (8.4)	0.5 ± 1.1 (0.8)	1.1 ± 1.8 (0.9)	
Does: amount is under goats if no kids observed	0.6 ± 3.2 (1.2)				19.4 ± 11.9 (4.1)	0.4 ± 0.9 (0.6)		1.6 ± 3.2 (1.4)
Kids:	1.8 ± 3.1 (1.9)				17.0 ± 12.9 (6.4)	0.3 ± 0.5 (0.3)		1.6 ± 3.1 (1.3)
Frequency in diet (%)								
Ewes	0	9	24	30	97	9	20	
Lambs	7				93	18	58	
Does	7	58	48	28	97	27		50
Kids	46				94	30		50
Percentage of diet by weight								
Ewes	0	Tr	0.2	0.2	11.9	Tr	0.2	
Lambs	Tr				4.9	0.1	1.0	
Does	0.2	1.2	0.5	0.2	9.2	0.1		0.5
Kids	0.6				5.0	0.1		1.3
Availability of plant								
Frequency in plots (%)	95	40	88	92	83	50	100	100
Phytomass (dry kg/ha)	81	48	125	17	46	24	100	318
% of all phytomass	7.4	8.0	11.3	11.4	69.5	6.7	29.2	67.7
Preference Index (% diet ÷ % availability)								
Ewes	0	0	0.02	0.02	0.17	0	0.01	
Lambs	0				0.07	0.01	0.03	
Does	0.03	0.15	0.04	0.02	0.13	0.01		0.01
Kids	0.08				0.07	0.01		0.02

* Significantly different from the value above at the .05 probability level.

Echiochilon fruticosum accounted for an average of 0.2 percent (range 0.0 to 0.6 percent) of the availability. Animals definitely preferred the species, though it was far from their favorite. In Pastures A and Begin B, goats took significantly more of their bites from it than did sheep.

Polygonum equisetiforme was also preferred but rare. It was never more than 0.1 percent of the availability, but it once was 13 percent of the diet of the kids. In Pastures A and End B, goats took significantly more of their bites from it than did sheep.

Retama raetam was found in biomass plots only in pastures A and C1, where it had 4 and 19 percent of the availabilities, respectively. Does took significantly more of their bites from the plant than did kids. Goats took significantly more of their bites from R. raetam than did sheep in three periods. Griego found that the diet of bucks contained 10 times more R. raetam than did the diet of rams. For A and C1 respectively, doe preference indices were 2.6 and 1.4, while ewe indices were 0.2 and 0.3. Qualitative observations in non-Project pastures indicated that goats found the flowers of R. raetam highly palatable, the fruits of good palatbility, and the leaves of moderate or even low palatability. The leaves were ingested primarily during summer and fall, when little other green phytomass was available.

Rhanterium suaveolens (Table 10.4) contributed an average of 20 percent (range 5 to 42 percent) of the availability in the eight periods. We suspect that the mere 5 percent (3 kg/ha) found in End B was less than the true value, thereby overestimating the preferences for R. sauveolens during End B. Still, by the End of B only 67 kg/ha of the present year's growth remained in the pasture, and 70 percent of this availability was unpalatable A. campestris. Therefore the animals were forced to eat R. suaveolens at an unusual intensity, even taking much phytomass of the previous year's growth. Similarly, the high preference of goats for R. suaveolens in C3 was partially due to unpalatable A. campestris accounting for 68 percent of the availability. End B and C3 aside, does exhibited moderate preferences for R. suaveolens, while ewe preferences were definitely on the low side. In all pastures except C1, goats took significantly more of their bites from the species than did sheep. During the use of C1 in 1976, we also found goats eating significantly more of their diet from the plant than did sheep (13.4.2 of Progress Report No. 5).

Griego stated that the leaves of mature R. suaveolens plants were preferred over those of immature plants; however, we noted exactly the opposite tendency. We also discerned, though, that flowers were much preferred over leaves. Perhaps the animals studied by Griego actually selected for flowers, and only incidentally "preferred" mature leaves because R. sauveolens should have been flowering during his observations.

Table 10 .4

Preference for *Rhanterium suaveolens*, a Nanophanerophyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	1.0 ± 1.7 (0.5)	10.5 ± 10.0 (3.1)	5.7 ± 6.8 (2.1)	5.6 ± 4.4 (1.4)	14.4 ± 11.3 (3.3)	5.8 ± 3.8 (1.7)	12.0 ± 9.8 (3.2)	
Goats: only does unless kid rate stated below	3.2* ± 4.6 (1.4)	26.3* ± 14.9 (4.6)	19.2* ± 10.7 (3.3)	22.5* ± 11.2 (3.4)	32.2* ± 15.9 (4.4)	8.3 ± 6.2 (2.8)		36.7 ± 12.8(3.8)
Ewes: amount is under sheep if no lambs observed	0.9 ± 1.8 (0.7)				18.2 ± 11.2 (4.0)	5.3 ± 3.6 (2.4)	16.6 ± 11.0 (5.2)	
Lambs:	1.1 ± 1.6 (0.9)				5.5* ± 4.1 (2.4)	6.3 ± 4.1 (2.8)	7.1* ± 5.0 (2.4)	
Does: amount is under goats if no kids observed	2.8 ± 5.1 (1.9)				36.6 ± 15.3 (5.3)	6.3 ± 3.5 (2.4)		36.1 ± 12.3(5.5)
Kids:	3.9 ±3.2 (1.9)				23.8* ± 13.9 (6.9)	10.5 ± 7.9 (5.7)		37.2 ± 13.5(5.7)
Frequency in diet (%)								
Ewes	37	88	76	90	100	91	100	
Lambs	40				93	100	100	
Does	60	100	100	100	100	100		100
Kids	85				100	100		100
Percentage of diet by weight								
Ewes	0.6	5.0	5.2	2.2	45.1	7.9	28.0	
Lambs	0.6				7.0	11.5	10.1	
Does	1.9	19.1	19.7	10.7	56.3	8.5		55.4
Kids	2.7				30.0	17.8		47.1
Availability of plant								
Frequency in plots (%)	100	100	100	100	100	100	100	100
Phytomass (dry kg/ha)	236	173	196	14	3[1]	75	144	69
% of all phytomass	21.5	29.0	17.8	9.0	4.8[1]	21.3	41.9	14.7
Preference Index (% diet ÷ % availability)								
Ewes	0.03	0.17	0.29	0.24	9.4[1]	0.37	0.67	
Lambs	0.03				1.5[1]	0.54	0.24	
Does	0.09	0.66	1.11	1.19	11.7[1]	0.40		3.8
Kids	0.13				6.3[1]	0.84		3.2

* Significantly different from the value above at the .05 probability level.

[1] The availability estimate is probably low; hence the preference indices are probably too high.

Salsola vermiculata brevifolia (Table 10.5) usually contributed between 1 and 10 percent of the availability of the present year's growth. Preference indices for the plant fluctuated widely possibly because estimates of the plant were biased due to the clumped distribution of the species in the pastures. Overall, we estimate that S. vermiculata was intermediate in preference -- neither preferred not unpreferred. In 4 periods, goats took significantly more of their bites from the species than did sheep. In 1 period, ewes took significantly more of their bites from the plant than did lambs; but in 1, kids took significantly more of their bites from the species than did does.

All nanophanerophytes together (Table 10.6) contributed an average of 58 percent (range 26 to 93 percent) of the availability during the 8 periods. Even though only the present year's growth was used in the calculation of the preference indices, the life-form was low in preference, largely owing to the effects of unpalatable Aristida pungens and Artemisia campestris. Other plants of the life-form rarely had high preferences, but they still provided much food, especially after the more palatable plants of the other life-forms had been eaten. Phytomass of nanophanerophytes grown during previous years provided emergency forage after the growth of the present year had been exhausted. The finding that goats took a larger percentage of their bites from nanophanerophytes than did sheep (in 5 periods significantly so), fits the traditional image of the goat as a browser. Ewes took more of their bites from the life-form than did lambs, possible because they were taller than lambs, or possibly lambs could select small, tender herbs more easily than could ewes.

Chamaephytes.-- These plants are perennial herbs or low shrubs that have their renewal buds above the soil, but the renewal buds are less than 25 cm high.

Anabasis oropediorum was a rare plant. It was apparently preferred forage, because animals ate most of its present year's growth as well as some of its previous year's growth whenever they came upon a plant.

Argyrolobium uniflorum (Table 10.7), a legume, contributed an average of 3.0 percent (range 0.2 to 8.3 percent) of the availability. It was one of the most preferred forages. Griego also found the species to be highly preferred, though his report called it Genista uniflora. We believe the plant is especially important on deferred pastures, because it stays green well into the summer. Twice sheep took significantly more of their bites from it than did goats.

Artemisia herba alba was a rare plant except in Begin B, where the species was 16 percent of the availability. Even there the species had an extremely low preference index -- 0.00. Such low palatability surprised us, because many people believe that the local animals derive their superb flavor from eating A. herba alba. Of course some people also believe that it makes the animals immune to snake bites!

Table 10.5

Preference for <u>Salsola vermiculata brevifolia</u>, a Nanophanerophyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	9.9 ± 10.3 (3.1)	7.9 ± 8.5 (2.6)	13.4 ± 11.3 (3.6)	9.2 ± 11.3 (3.6)	11.9 ± 11.8 (3.5)	4.6 ± 4.1 (1.8)	32.0 ± 12.6 (4.1)	
Goats: only does unless kid rate stated below	7.6 ± 7.4 (2.3)	25.0* ± 17.0 (5.2)	19.8* ± 11.4 (3.5)	8.1 ± 7.0 (2.2)	25.4* ± 14.4 (4.0)	7.6* ± 4.6 (2.1)		11.0 ± 7.1 (2.1)
Ewes: amount is under sheep if no lambs observed	10.9 ± 10.6 (4.0)				13.9 ± 12.6 (4.5)	7.4 ± 3.9 (2.6)	33.2 ± 13.3 (6.2)	
Lambs:	8.0 ± 9.7 (5.3)				7.1 ± 8.0 (4.6)	1.9* ± 1.7 (1.2)	30.7 ± 12.0 (5.8)	
Does: amount is under goats if no kids observed	6.0 ± 6.2 (2.3)				23.9 ± 14.5 (5.0)	7.2 ± 4.6 (3.1)		13.7 ± 6.6 (2.9)
Kids:	11.3* ± 8.8 (5.3)				28.4 ± 13.9 (6.9)	8.0 ± 4.7 (3.4)		8.5* ± 6.8 (2.9)
Frequency in diet (%)								
Ewes	93	81	90	88	97	100	100	
Lambs	87				64	91	100	
Does	83	98	98	93	97	100		100
Kids	85				100	100		96
Percentage of diet by weight								
Ewes	4.0	2.7	3.7	5.3	11.0	7.0	33.5	
Lambs	2.6				2.7	1.9	23.6	
Does	2.4	13.1	6.2	5.7	11.7	6.1		12.6
Kids	4.4				10.5	7.6		5.8
Availability of plant								
Frequency in plots (%)	95	50	67	71	86	83	62	80
Phytomass (dry kg/ha)	46.6	5.1	24.4	7.7	12.4[1]	36.6	3.5	10.8
% of all phytomass	4.2	0.9	2.2	5.0	18.6[1]	10.3	1.0	2.3
Preference Index (% diet ÷ % availability)								
Ewes	1.0	3.0	1.7	1.1	0.6[1]	0.7	33.5	
Lambs	0.6				0.1[1]	0.2	23.6	
Does	0.6	14.6	2.8	1.1	0.6[1]	0.6		5.5
Kids	1.0				0.6[1]	0.7		2.5

* Significantly different from the value above at the .05 probability level.

[1] The availability estimate is probably too high; hence the preference indices are probably too low.

Table 10.6

Preference for All Nanophanerophytes Combined by Sheep and Goats
August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	10.9 ± 10.7 (3.2)	18.6 ± 12.1 (3.7)	22.6 ± 12.3 (3.9)	15.6 ± 13.7 (4.4)	42.1 ± 19.6 (5.7)	14.6 ± 7.2 (3.2)	45.4 ± 13.1 (4.2)	
Goats: only does unless kid rate stated below	12.1 ± 10.2 (3.2)	56.1* ± 18.1 (5.6)	52.5* ± 14.9 (4.5)	33.2* ± 14.4 (4.4)	78.5* ± 13.5 (3.7)	34.3* ± 12.2 (5.6)		51.2 ± 12.9(3.
Ewes: amount is under sheep if no lambs observed	11.8 ± 11.1 (4.1)				47.6 ± 17.8 (6.3)	16.9 ± 7.2 (4.8)	50.8 ± 12.2 (5.7)	
Lambs:	9.2 ± 9.9 (5.5)				29.3* ± 18.1(10.5)	12.2 ± 6.6 (4.4)	39.7* ± 11.7 (5.7)	
Does: amount is under goats if no kids observed	9.6 ± 8.4 (3.1)				81.7 ± 9.1 (3.1)	33.8 ± 11.4 (7.7)		53.4 ±12.6(5.6
Kids:	17.7* ±12.1 (7.3)				72.1* ± 18.1 (9.)0	35.0 ± 13.7 (9.8)		49.2 ±13.2(5.6
Frequency in diet (%)								
Ewes	100	100	100	98	100	100	100	
Lambs	93				100	100	100	
Does	90	100	100	100	100	100		100
Kids	92				100	100		100
Percentage of diet by weight								
Ewes	4.6	7.8	12.2	7.8	67.9	20.9	62.0	
Lambs	3.3				15.7	18.9	35.0	
Does	4.5	34.9	45.4	17.3	84.0	42.9		69.5
Kids	7.9				60.7	48.6		54.8
Availability of plant								
Frequency in plots (%)	100	100	100	100	100	100	100	100
Phytomass (dry kg/ha)	373	226	666	39	62	206	249	398
% of all phytomass	33.9	37.9	60.3	25.6	93.1	58.1	72.6	84.8
Preference Index (% diet ÷ % availability)								
Ewes	0.14	0.21	0.20	0.30	0.73	0.36	0.85	
Lambs	0.10				0.17	0.33	0.48	
Does	0.13	0.92	0.75	0.68	0.90	0.74		0.82
Kids	0.23				0.65	0.84		0.65

* Significantly different from the value above at the .05 probability level.

Table 10.7

Preference for Argyrolobium uniflorum, a Chamaephyte, by Goats and Sheep, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	40.6 ± 14.9 (4.5)	5.3 ± 5.7 (1.8)	4.4 ± 4.8 (1.5)	14.2 ± 10.1 (3.2)	7.0 ± 7.3 (2.1)	6.4 ± 4.9 (2.2)	10.2 ± 8.2 (2.6)	
Goats: only does unless kid rate stated below	40.9 ± 15.2 (4.7)	4.1 ± 4.9 (1.5)	3.5 ± 3.9 (1.2)	10.6 ± 9.4 (2.9)	2.7* ± 4.2 (1.2)	2.4* ± 3.7 (1.7)		13.6 ±8.6(2.6)
Ewes: amount is under sheep if no lambs observed	39.7 ± 14.8 (5.5)				6.6 ± 7.3 (2.6)	4.4 ± 3.9 (2.6)	6.8 ± 6.6 (3.1)	
Lambs:	42.4 ± 15.6 (8.7)				8.0 ± 7.6 (4.4)	8.5* ± 5.1 (3.4)	13.7* ± 8.3 (4.0)	
Does: amount is under goats if no kids observed	39.1 ± 15.9 (5.9)				2.6 ± 4.3 (1.5)	0.9 ± 1.2 (0.8)		11.1 ±7.9(3.5)
Kids:	45.0 ± 12.9 (7.8)				3.0 ± 4.3 (2.1)	4.2 ± 4.7 (3.4)		15.9 ±8.8(3.7)
Frequency in diet (%)								
Ewes	100	81	78	100	88	100	80	
Lambs	100				93	100	100	
Does	100	70	68	91	40	64		100
Kids	100				50	80		100
Percentage of diet by weight								
Ewes	45.3	1.7	3.2	11.3	5.2	4.9	5.6	
Lambs	43.8				9.5	8.3	17.4	
Does	47.8	2.0	2.9	10.3	1.3	0.9		8.3
Kids	54.9				3.6	3.8		17.9
Availability of plant								
Frequency in plots (%)	90	70	67	100	83	100	89	98
Phytomass (dry kg/ha)	49.1	1.2	3.9	8.8	0.6	29.3	7.1	6.2
% of all phytomass	4.5	0.2	0.4	5.8	1.0	8.3	2.1	1.3
Preference Index (% diet ÷ % availability)								
Ewes	10	9	8	1.9	5.2	0.6	2.7	
Lambs	10				9.5	1.0	8.3	
Does	11	10	7	1.8	1.3	0.1		6
Kids	12				3.6	0.5		14

* Significantly different from the value above at the .05 probability level.

Citrullus coloscynthis was a rare plant. It is thought to be poisonous (Novikoff pers. comm.). Although its fleshy fruits were eaten at times, its leaves were never eaten.

Erodium glaucophyllum was harvested only in Begin D2 and C1, and then at less than 0.5 percent of the availabilities. The preference indices for Begin D2 and C1, respectively, were 4 and 31 for ewes and 27 and 37 for does. Goats often moved from plant to plant of E. glaucophyllum, skipping the other species in between.

Fagonia glutinosa accounted for an average of 0.3 percent (range 0.0 to 1.2 percent) of the availability. On the average its preference indices were about 1.0. We suspect that it was highly palatable but difficult to select because of its prostrate form.

Gymnocarpus decander never amounted to more than 0.1 percent of the availability. It was apparently highly preferred, as it was eaten intensively whenever it was found.

Haloxylon tamaricifoliam was also a rare species that seemed to be preferred.

Helianthemum lippii (Table 10.8) contributed an average of 1.2 percent (range 0.1 to 4.7 percent) of the availability. It appeared to be palatable, because its preference rating (averaged over all animals) dropped below 1.0 only at Begin D2 and Begin C1, when much highly palatable forage was available. Goats took a larger percentage of their bites from the species than did sheep, in 4 periods significantly so.

Linaria aegyptiaca (Table 10.9) accounted for an average of 2.2 percent (ragne 0.4 to 7.0 percent) of the availability in the 8 periods. Goats took more of their bites from the species than did sheep, significantly so in 2 periods. It was preferred forage in End D2, A, and End B, when more palatable species such as E. glaucophyllum, Nolletia chrysocomoides, Plantago albicans, and Zollikoferia residifolia were rare.

Nolletia chrysocomoides (Table .10, formerly called Inula chrysocomoides) contributed an average of 0.8 percent (range 0.0 to 2.5 percent) of the availability. It was preferred forage in all periods except Begin B, when much highly palatable forage was available. Sheep and goats usually took similar percentages of their bites from the species, though in C1 in 1976 goats ate significantly more than did sheep (13.4.2 of Progress Report No. 5).

Pituranthos tortuosus contributed an average of 0.2 percent (range 0.0 to 0.7 percent) of the availability for all periods except Begin B, when it was 6 percent. Goats took significantly more of their bites from it than did sheep in four periods. After deleting Begin B when P. tortuosus had low ratings, the average of the goat indices for the species was 5.3 (range 2.0 to 7.5), and the average sheep preference for the plant was 1.9 (range 1.3 to 2.9).

Table 10.8

Preference for Helianthemum lippii sessiliflorum, a Chamaephyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	0.6 ± 2.3 (0.7)	0.1 ± 0.5 (0.2)	0.9 ± 1.4 (0.5)	1.8 ± 3.1 (1.0)	0.5 ± 1.1 (0.3)	3.6 ± 2.9 (1.4)	2.1 ± 2.7 (0.9)	
Goats: only does unless kid rate stated below	2.4* ± 3.0 (0.9)	2.1* ± 4.6 (1.4)	1.5 ± 2.3 (0.7)	5.1* ± 6.9 (2.1)	1.4* ± 3.0 (0.8)	4.3 ± 4.3 (2.0)		4.4 ±4.6(1.4)
Ewes: amount is under sheep if no lambs observed	0.2 ± 0.5 (0.2)				0.4 ± 1.2 (0.4)	2.4 ± 1.9 (1.3)	1.3 ± 1.9 (0.9)	
Lambs:	1.5 ± 3.9 (2.2)				0.6 ± 1.1 (0.6)	4.8* ± 3.3 (2.2)	2.8 ± 3.1 (1.5)	
Does: amount is under goats if no kids observed	2.0 ± 2.9 (1.1)				0.7 ± 1.6 (0.5)	3.1 ± 3.0 (2.0)		2.4 ±2.4(1.1)
Kids:	3.3 ± 3.1 (1.9)				2.8 ± 4.3 (2.2)	5.6 ± 5.3 (3.8)		6.2* ±5.4(2.3)
Frequency in diet (%)								
Ewes	13	9	41	40	21	91	50	
Lambs	13				29	91	68	
Does	47	42	48	70	23	91		77
Kids	69				50	90		88
Percentage of diet by weight								
Ewes	0.1	Tr	0.3	0.7	0.4	2.5	1.0	
Lambs	0.9				0.4	3.0	2.4	
Does	1.4	0.8	0.6	2.6	0.4	3.0		1.7
Kids	2.3				2.1	3.3		4.7
Availability of plant								
Frequency in plots (%)	60	30	38	57	67	84	68	83
Phytomass (dry kg/ha)	24.0	1.5	1.1	1.0	0.1	16.6	2.9	1.9
% of all phytomass	2.2	0.3	0.1	0.7	0.2	4.7	0.8	0.4
Preference Index (% diet ÷ % availability)								
Ewes	0.1	0.1	3.0	1.0	2.0	0.5	1.3	
Lambs	0.4				2.0	0.6	3.0	
Does	0.6	2.7	6.0	3.7	2.0	0.6		4.3
Kids	1.0				10.5	0.7		11.8

* Significantly different from the value above at the .05 probability level.

Table 10.9

Preference for <u>Linaria aegyptiaca fruticosa</u>, a Chamaephyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	0.1 ± 0.5 (0.2)	0.4 ± 1.0 (0.2)	1.6 ± 2.4 (0.7)	1.1 ± 1.7 (0.6)	2.2 ± 2.9 (0.9)	0.5 ± 1.1 (0.5)	4.3 ± 4.5 (1.4)	
Goats: only does unless kid rate stated below	0.1 ± 0.5 (0.1)	1.8* ± 3.4 (1.1)	3.0 ± 3.8 (1.2)	3.9* ± 3.9 (1.2)	3.7 ± 5.2 (1.4)	0.9 ± 1.3 (0.6)		4.1 ± 4.3 (1.3)
Ewes: amount is under sheep if no lambs observed	0.1 ± 0.7 (0.3)				2.1 ± 3.1 (1.1)	0.1 ± 0.2 (0.1)	4.6 ± 4.1 (1.9)	
Lambs:	0				2.4 ± 2.4 (1.4)	0.9 ± 1.4 (0.9)	4.1 ± 4.9 (2.3)	
Does: amount is under goats if no kids observed	Tr ± 0.1 (T)				3.0 ± 4.2 (1.4)	1.1 ± 1.6 (1.0)		4.8 ± 5.5 (2.5)
Kids:	0.4 ± 0.8 (0.5)				5.0 ± 6.7 (3.3)	0.6 ± 1.1 (0.8)		3.5 ± 2.8 (1.2)
Frequency in diet (%)								
Ewes	3	19	54	45	58	27	90	
Lambs	0				64	55	79	
Does	3	33	68	86	54	55		91
Kids	31				56	40		88
Percentage of diet by weight								
Ewes	Tr	0.1	0.7	0.4	4.5	0.1	3.1	
Lambs	0				5.2	0.7	3.1	
Does	Tr	1.0	1.6	1.9	4.0	0.8		3.0
Kids	0.2				10.7	0.4		2.4
Availability of plant								
Frequency in plots (%)	65	20	71	92	75	62	100	94
Phytomass (dry kg/ha)	11.5	2.4	4.9	2.7	0.7	11.2	23.8	11.6
% of all phytomass	1.0	0.4	0.4	1.8	1.1	3.2	7.0	2.5
Preference Index (% diet ÷ % availability)								
Ewes	Tr	0.3	1.8	0.2	4.1	Tr	0.4	
Lambs	0				4.7	0.2	0.4	
Does	Tr	2.5	4.0	1.1	3.6	0.3		1.2
Kids	0.2				9.7	0.1		1.0

* Significantly different from the value above at the .05 probability level.

Table 10.10

Preference for Nolletia chrysocomoides, a Chamaepyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	23.5 ± 14.4 (4.3)	0.8 ± 1.4 (0.4)	1.9 ± 2.0 (0.9)	2.0 ± 3.1 (1.0)	0.4 ± 1.2 (0.3)	5.9 ± 2.9 (1.3)	1.1 ± 1.7 (0.6)	
Goats: only does unless kid rate stated below	26.6 ± 15.2 (4.7)	1.8 ± 2.8 (0.9)	1.6 ± 2.0 (0.6)	1.8 ± 3.1 (1.0)	0.4 ± 1.4 (0.4)	5.9 ± 3.4 (1.6)		0.6 ± 1.4 (0.4)
Ewes: amount is under sheep if no lambs observed	24.5 ± 14.1 (5.3)				0.3 ± 1.0 (0.2)	5.9 ± 2.6 (1.8)	1.2 ± 1.4 (0.7)	
Lambs:	21.6 ± 15.3 (8.5)				0.6 ± 1.5 (0.9)	5.9 ± 3.3 (2.2)	0.9 ± 2.0 (1.0)	
Does: amount is under goats if no kids observed	29.7 ± 16.0 (6.0)				0.5 ± 1.2 (0.4)	7.9 ± 3.1 (2.1)		1.0 ± 2.0 (0.9)
Kids:	19.3* ± 10.5 (6.3)				0.4 ± 1.8 (0.9)	3.7* ± 2.2 (1.6)		0.3 ± 0.6 (0.3)
Frequency in diet (%)								
Ewes	97	35	63	40	12	100	55	
Lambs	100				14	100	21	
Does	97	49	59	40	17	100		32
Kids	100				6	100		21
Percentage of diet by weight								
Ewes	22.8	0.1	0.6	1.1	0.4	6.6	0.9	
Lambs	18.2				0.4	3.6	0.5	
Does	29.7	0.2	0.6	1.2	0.5	8.0		0.7
Kids	19.3				0.3	2.1		0.2
Availability of plant								
Frequency in plots (%)	85	70	0	28	33	81	26	17
Phytomass (dry kg/ha)	27.0	0.5		2.3	0.1	6.6	0.1	0.1
% of all phytomass	2.5	0.1		1.5	0.2	1.9	Tr	Tr
Preference Index (% diet ÷ % availability)								
Ewes	9	1	>>1	1	2	3	>>1	
Lambs	7				2	2	>>1	
Does	12	2	>>1	1	3	4		>>1
Kids	8				2	1		>>1

* Significantly different from the value above at the .05 probability level.

All chamaephytes together (Table 10.11) contributed an average of 11 percent (range 0.9 to 34) of the availability during the 8 periods. Goats tended to take more of their bites from the life-form than did sheep, in 2 periods significantly so. The average doe preference for chamaephytes was 4.1 (± 2.9 SD), and the average ewe preference was 2.9 (± 2.3 SD). Although most species of the life-form were preferred, A. herba alba and C. coloscythis had low preferences.

Hemicryptophytes.-- The renewal buds of these perennial herbs are barely embedded in the surface of the soil.

Astragalus gyzensis usually contributed less than 0.05 percent of the availability, but in C2 it had 0.2 percent. Except for a rare nibble, animals passed the plant by. We judge it to have very low palatability.

The Atractylis genus consists of two species: A. candida which is usually a therophyte but is sometimes a hemicryptophyte, depending upon the rainfall; and A. serratiloides which is a chamaephyte or a hemicryptophyte. The biomass crews did not distinguish between the two species; therefore we lumped the two under hemicryptophytes. The availability of Atractylis spp. averaged 1.0 percent (range 0.1 to 3.0 percent) of the total. Goats tended to take more bites from the species than did sheep, significantly so in C1 and Begin D2, as well as in C1 in 1976 (13.4.2 of Progress Report No. 5). Preferences for this prickly genus ranged from about 2 during End B, when little palatable forage was present, to 0.02 in C1 and C2, when many tender plants of other species were available.

Plantago albicans (Table 10.12) contributed under 6 percent of the availability in all periods in which it was measured except Begin B, when it composed 27 percent of the availabilility. Sheep always took significantly more of their bites from this species than did goats, which also happened in C1 in 1976 (13.4.2 of Progress Report No. 5). Griego also saw sheep eat more P. albicans. Sheep preferences for the plant tended to be high, but goat preferences for it tended to be low. Sheep preference for the species was low, though, in Begin B when many highly palatable plants were present. P. albicans appears to provide excellent forage on deferred range, because its leaves remain green well into the summer. Indeed, in 1976 many leaves lived through summer and again became succulent with the arrival of the fall rains. Also, P. albicans was important during fall, for it sprouted new leaves earlier than most sepcies.

Zollikoferia resedifolia (Table 10.13) contributed an average of 4.2 percent (range 0.6 to 11.4 percent) of the availability during winter and spring. It was possibly the most preferred species because its index was high even in Begin B, when other palatable species showed their lowest indices owing to the presence of many highly palatable plants. In Pasture B sheep took significantly more of their bites from Z. resedifolia than did goats, but in C1 in 1976 does ate significantly more of it than did ewes (13.4.2 of Progress Report No. 5).

Table 10.11

Preference for All Chamaephytes Combined by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD (CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	66.1 ± 12.9 (3.9)	6.8 ± 6.5 (2.0)	9.5 ± 7.0 (2.2)	21.0 ± 12.0 (3.8)	11.6 ± 9.3 (2.7)	19.7 ± 7.7 (3.4)	21.5 ± 9.0 (2.9)	
Goats: only does unless kid rate stated below	77.4* ± 12.4 (3.8)	10.3 ± 10.5 (3.2)	11.6 ± 7.8 (2.4)	27.8* ± 13.4 (4.1)	14.0 ± 9.6 (2.6)	18.4 ± 9.4 (4.3)		27.0 ± 10.9 (3.2)
Ewes: amount is under sheep if no lambs observed	65.9 ± 14.0 (5.2)				10.4 ± 9.3 (3.3)	16.7 ± 6.7 (4.5)	18.4 ± 7.5 (3.5)	
Lambs:	66.6 ± 10.6 (5.9)				14.4 ± 9.1 (5.3)	22.7 ± 7.8 (5.2)	24.7* ± 9.5 (4.6)	
Does: amount is under goats if no kids observed	79.6 ± 12.7 (4.7)				12.3 ± 7.6 (2.6)	19.1 ± 6.8 (4.6)		24.6 ± 11.9 (5.3)
Kids:	72.4 ± 10.7 (6.5)				17.2 ± 12.2 (6.1)	17.6 ± 12.0 (8.6)		29.3 ± 9.5 (4.0)
Frequency in diet (%)								
Ewes	100	88	98	100	97	100	100	
Lambs	100				100	100	100	
Does	100	86	98	100	94	100		100
Kids	100				100	100		100
Percentage of diet by weight								
Ewes	69.5	2.0	5.3	14.7	11.8	21.1	14.3	
Lambs	63.7				18.6	20.1	27.0	
Does	87.1	4.2	7.4	19.9	10.6	20.8		16.8
Kids	80.7				25.7	14.0		27.8
Availability of plant								
Frequency in plots (%)	100	100	95	100	97	100	100	100
Phytomass (dry kg/ha)	114.8	5.6	11.3	51.3	2.0	65.8	42.0	24.0
% of all phytomass	10.5	0.9	1.0	33.5	3.1	18.6	12.3	5.1
Preference Index (% diet ÷ % availability)								
Ewes	6.6	2.2	5.3	0.4	3.8	1.1	1.2	
Lambs	6.1				6.0	1.1	2.2	
Does	8.3	4.7	7.4	0.6	3.4	1.1		3.3
Kids	7.7				8.3	0.8		5.5

* Significantly different from the value above at the .05 probability level.

Table 10 .12

Preference for <u>Plantago albicans</u>, a Hemicrypotophyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	10.3 ± 10.4 (3.1)	0	21.7 ± 12.1 (3.8)	6.9 ± 7.5 (2.4)	15.9 ± 10.2 (3.0)	11.3 ± 5.4 (2.4)	19.2 ± 11.8 (3.8)	
Goats: only does unless kid rate stated below	1.2* ± 3.9 (1.2)	0	2.5* ± 3.4 (1.1)	3.3* ± 5.5 (1.7)	2.3* ± 3.9 (1.1)	3.5* ± 3.7 (1.7)		8.4 ±6.8(2.0)
Ewes: amount is under sheep if no lambs observed	11.0 ± 11.1 (4.1)				16.1 ± 10.8 (3.8)	11.2 ± 6.3 (4.2)	18.0 ± 11.7 (5.5)	
Lambs:	9.0 ± 9.1 (5.0)				15.3 ± 8.9 (5.1)	11.4 ± 4.7 (3.1)	20.5 ± 12.2 (5.9)	
Does: amount is under goats if no kids observed	1.5 ± 4.7 (1.7)				1.6 ± 2.1 (0.7)	3.4 ± 3.6 (2.4)		8.4 ±7.7(3.4)
Kids:	0.5 ± 0.9 (0.6)				3.7 ± 5.9 (3.0)	3.6 ± 4.0 (2.9)		8.4 ±6.0(2.5)
Frequency in diet (%)								
Ewes	83	0	98	78	100	100	100	
Lambs	67				93	100	100	
Does	30	0	64	49	49	91		100
Kids	31				61	70		100
Percentage of diet by weight								
Ewes	10.6	0	6.8	2.8	8.9	8.1	18.4	
Lambs	7.8				23.8	11.2	29.8	
Does	1.5	0	0.9	1.6	0.6	2.2		7.8
Kids	0.5				5.8	3.3		10.9
Availability of plant								
Frequency in plots (%)	Not clipped separately	Not clipped separately	Not clipped	92	67	68	95	83
Phytomass (dry kg/ha)				41.3	1.6	20.5	11.9	16.3
% of all phytomass				27.0	2.4	5.8	3.5	3.5
Preference Index (% diet ÷ % availability)								
Ewes	?	?	?	0.1	3.7	1.4	5.3	
Lambs	?				9.9	1.9	8.5	
Does	?	?	?	0.1	0.3	0.4		2.2
Kids	?				2.4	0.6		3.1

* Significantly different from the value above at the .05 probability level.

Table 10 .13

Preference for Zollikoferia resedifolia, a Hemicryptophyte, by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	2.1 ± 3.1 (0.9)	0	0.2 ± 0.5 (0.2)	48.8 ± 18.1 (5.8)	4.8 ± 6.0 (1.8)	35.5 ± 8.8 (3.9)	6.4 ± 4.1 (1.3)	
Goats: only does unless kid rate stated below	3.1 ± 2.7 (0.8)	0	0.5 ± 1.2 (0.4)	32.7* ± 14.3 (4.4)	1.6* ± 3.2 (0.9)	35.3 ± 9.1 (4.1)		8.5 ± 6.0(1.8)
Ewes: amount is under sheep if no lambs observed	2.2 ± 3.4 (1.3)				5.1 ± 6.7 (2.4)	37.0 ± 8.7 (5.9)	7.3 ± 4.4 (2.0)	
Lambs:	2.0 ± 2.6 (1.4)				4.2 ± 3.8 (2.2)	34.1 ± 9.1 (6.1)	5.4 ± 3.7 (1.8)	
Does: amount is under goats if no kids observed	3.4 ± 2.8 (1.0)				1.5 ± 3.0 (1.0)	36.6 ± 7.4 (4.9)		8.2 ± 6.9 (3.0)
Kids:	2.2 ± 2.4 (1.5)				1.8 ± 3.5 (1.7)	33.9 ± 10.9 (7.8)		8.7 ± 5.3 (2.2)
Frequency in diet (%)								
Ewes	60	0	22	100	67	100	100	
Lambs	53				79	100	95	
Does	90	0	20	100	31	100		96
Kids	69				33	100		100
Percentage of diet by weight								
Ewes	1.7	0	Tr	73.8	1.3	32.2	4.1	
Lambs	1.4				3.1	25.2	3.1	
Does	2.7	0	Tr	60.4	0.2	28.8		4.1
Kids	1.8				1.3	23.2		4.4
Availability of plant								
Frequency in plots (%)	Not clipped separately	Not clipped separately	Not clipped	92	89	98	100	91
Phytomass (dry kg/ha)				17.5	0.6	23.7	4.3	3.0
% of all phytomass				11.4	0.9	6.7	1.3	0.6
Preference Index (% diet ÷ % availability)								
Ewes	?	?	?	6.5	1.4	4.8	3.2	
Lambs	?				3.4	3.8	2.4	
Does	?	?	?	5.3	0.2	4.3		6.8
Kids	?				1.4	3.5		7.3

* Significantly different from the value above at the .05 probability level.

Both sheep and goats relished the blossoms of this plant. Griego's data also indicate that *Z. resedifolia* is highly preferred by both sheep and goats.

All hemicryptophytes together (Table 10.14) contributed an average of 14 percent (range 3.5 to 39 percent) of the availability, not counting pastures D2 and A when the availabilities of green hemicryptophytes were not measured. During the periods when their green availabilities were measured, hemicryptophytes composed 38 percent (range 11 to 77 percent) of the ewe diet and 27 percent (range 1 to 62 percent) of the doe diet. Green hemicrypotophytes were apparently highly palatable for both animals, though sheep preferred them more than did goats. In 5 periods sheep took significantly more of their bites from the life-form than did goats. The palatability of hemicryptophytes is probably enhanced by the lack of above-ground woody parts. With nanophanerophytes and chamaephytes animals attempt to avoid their woody parts while selecting their green parts, which increases the time involved in selecting a bite. Only two species of hemicryptophytes had low preferences: *Astragalus gyzensis* was possibly poor tasting, and *Atractylis* spp. were thorny.

Geophytes.-- The renewal buds of these perennials are well covered by soil.

Lygaeum spartum contributed an average of 0.5 percent (range 0 to 3 percent) of the availability in the 8 periods. Goats took significantly more of their bites from the species than did sheep, during A and End B. The sheep preference for *L. spartum* never rose above 0.4, but the doe preference ranged from 0 to 12. Preference was high during End B partially because other species had already been eaten away until an adult bite on them weighed between 10 and 226 mg, while an adult bite on *L. spartum* weighed 360 mg owing to the species still being largely intact.

Stipa fontanesii accounted for an average of 0.5 percent (range 0.0 to 2.3 percent) of the availability. Bites of *S. fontanesii* were larger than those of most species, which contributed to its average preference rating of about 1.0.

All geophytes together (Table 10.15) averaged 1.0 percent (range 0.0 to 3.2 percent) of the availability during the 8 periods. The species in this life-form happened to be bunchgrasses. They tended to have low preference indices when much choice was available, possibly because they were tough. The bunchgrasses were preferred forages, though, when forage was scarce, possibly because animals could take large bites from them. Plants belonging to the geophyte group remained predominantly green even into fall in 1976.

Therophytes.-- These plants are annuals, or those plants in which the renewal bud is protected by a seed coat.

Table 10.14

Preference for All Hemicryptophytes Combined by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	12.5 ± 10.4 (3.1)	0	22.2 ± 12.3 (3.9)	55.9 ± 17.8 (5.7)	21.3 ± 11.3 (3.3)	46.9 ± 9.9 (4.4)	25.8 ± 11.2 (3.6)	
Goats: only does unless kid rate stated below	4.5* ± 5.4 (1.7)	0	3.7* ± 4.0 (1.2)	36.4* ± 15.1 (4.7)	4.6* ± 5.7 (1.6)	39.0* ± 9.6 (4.4)		17.3 ± 7.9 (2.3)
Ewes: amount is under sheep if no lambs observed	13.2 ± 11.4 (4.3)				21.8 ± 12.1 (4.3)	48.3 ± 9.1 (6.1)	25.5 ± 11.0 (5.1)	
Lambs:	11.1 ± 8.2 (4.5)				20.2 ± 9.3 (5.3)	45.5 ±10.8 (7.3)	26.0 ± 11.6 (5.6)	
Does: amount is under goats if no kids observed	5.3 ± 6.1 (2.3)				3.4 ± 3.9 (1.3)	39.9 ± 8.6 (5.8)		17.2 ± 9.7(4 3)
Kids:	2.8 ± 2.9 (1.8)				6.9 ± 7.9 (3.9)	37.9 ± 10.9(7.8)		17.3 ± 5/9 (2.5)
Frequency in diet (%)								
Ewes	93	0	98	100	100	100	100	
Lambs	87				100	100	100	
Does	93	0	84	100	69	100		100
Kids	69				78	1-0		100
Percentage of diet by weight								
Ewes	12.2	0	6.9	76.6	10.6	40.5	22.5	
Lambs	9.2				27.7	36.4	32.9	
Does	4.7	0	1.0	62.1	0.9	31.0		12.6
Kids	2.4				8.7	27.0		15.4
Availability of plant								
Frequency in plots (%)	Not clipped separately	Not clipped separately	Not clipped	100	94	100	100	100
Phytomass (dry kg/ha)				59.9	2.3	52.8	27.2	20.1
% of all phytomass				39.2	3.5	14.9	7.9	4.3
Preference Index (% diet ÷ % availability)								
Ewes	?	?	?	2.0	3.0	2.7	2.8	
Lambs	?				7.9	2.4	4.2	
Does	?	?	?	1.6	0.3	2.1		2.9
Kids	?				2.5	1.8		3.6

* Significantly different from the value above at the .05 probability level.

Table 10.15

Preference for All Geophytes Combined by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	0.3 ± 0.8 (0.2)	1.5 ± 3.4 (1.0)	0.9 ± 1.9 (0.6)	0.2 ± 0.6 (0.2)	0.2 ± 0.7 (0.2)	0.1 ± 0.3 (0.1)	0.1 ± 0.5 (0.2)	
Goats: only does unless kid rate stated below	Tr* ± 0.2 (T)	0.5 ± 1.6 (0.5)	3.0* ± 4.0 (1.2)	0.5 ± 1.4 (0.4)	0.7 ± 2.0 (0.5)	0.1 ± 0.3 (0.1)		0
Ewes: amount is under sheep if no lambs observed	0.3 ± 0.9 (0.2)				0.2 ± 0.8 (0.3)	0	0.1 ± 0.6 (0.3)	
Lambs:	0.1 ± 0.6 (0.3)				0.1 ± 0.3 (0.2)	0.2 ± 0.4 (0.3)	0.1 ± 0.5 (0.2)	
Does: amount is under goats if no kids observed	Tr ± 0.2 (0.1)				0.8 ± 2.2 (0.8)	0.1 ± 0.2 (0.1)		0
Kids:	0				0.6 ± 1.5 (0.7)	0.2 ± 0.4 (0.3)		0
Frequency in diet (%)								
Ewes	13	40	34	8	9	0	5	
Lambs	7				7	27	5	
Does	3	14	66	14	11	9		0
Kids	0				17	20		0
Percentage of diet by weight								
Ewes	0.4	0.4	0.8	0.2	0.9	0	0.1	
Lambs	0.2				0.2	0.1	0.1	
Does	0.1	0.2	2.9	0.4	4.1	0.1		0
Kids	0				1.5	0.1		0
Availability of plant								
Frequency in plots (%)	25	0	33	21	11	39	15	9
Phytomass (dry kg/ha)	7.2		35.5	1.0	0.2	8.8	0.2	1.6
% of all phytomass	0.7		3.2	0.7	0.3	2.5	Tr	0.3
Preference Index (% diet ÷ % availability)								
Ewes	0.6	>1	0.3	0.3	3.0	0.0	?	
Lambs	0.3				0.7	Tr	?	
Does	0.1	>1	0.9	0.6	13.7	Tr		0.0
Kids	0.0				5.0	Tr		0.0

* Significantly different from the value above at the .05 probability level.

All therophytes together (Table 10.16) never accounted for over 7 percent of the availability during the 8 periods. In 4 periods sheep took significantly more of their bites from the life-form than did goats. When the therophytes were fully grown in Begin C1, they had preference indices of 2.6 for ewes and 0.9 for does -- less than the hemicryptophytes. Preferences for the same species of therophytes calculated for Griego's data for Begin C1 were 4.0 for rams and 1.1 for bucks. In the other three periods for which the availabilities of therophytes were measured, therophytes had low preference ratings (Table 10.16). We suspect that most species of therophytes are highly palatable; however, during dry years like those from which the above indices came, individual therophytes tend to be smaller than hemicryptophytes. Thus bites on P. albicans and Z. resedifolia tended to be larger than bites on therophytes, causing the relative contributions to the diet of a bite of hemicryptophyte to be larger than that of a therophyte. Also animals probably were inclined to eat more often from plants which they could take larger bites. In summary, therophytes showed lower preference indices than hemicryptophytes, but therophytes may have been just as tasty. In a year with much rainfall, such as 1975-76, therophytes grow much larger and probably have much higher preference indices.

Following is a list of species which we consider to be therophytes, along with their preferences in 1977 relative to other therophytes:

High preference:

Dancus syrticus
Diplotaxis spp.
Hedysarum spinosissimum
Mathiola longipetala kralickii
Reseda alba
Senecio delphinifolius

Average preference:

Asphodelus refractus
Echinopsilon muricatus
Lotus pusillus
Medicago littoralis

Lower preference:

Bupleurum lancifolium
Cutandia divaricata
Hordeum murinum
Ifloga spicata
Malva aegyptiaca
Schismus barbatus

Table 10.16

Preference for all Therophytes Combined by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	1.0 ± 1.8 (0.5)	0	8.1 ± 7.2 (2.3)	7.0 ± 7.7 (2.5)	24.2 ± 16.8 (4.9)	17.9 ± 6.0 (2.6)	7.3 ± 5.5 (1.8)	
Goats: only does unless kid rate stated below	2.4 ± 5.5 (1.7)	0	3.3* ± 5.2 (1.6)	2.1* ± 5.4 (1.7)	2.3* ± 4.0 (1.1)	8.2* ± 4.4 (2.0)		4.4 ± 3.7 (1.1)
Ewes: amount is under sheep if no lambs observed	1.3 ± 2.1 (0.8)				19.2 ± 13.5 (4.8)	17.2 ± 5.8 (3.9)	5.2 ± 4.0 (1.9)	
Lambs:	0.2* ± 0.7 (0.4)				36.0* ± 18.2 (10.5)	18.7 ± 6.3 (4.2)	9.5* ± 6.1 (2.9)	
Does: amount is under goats if no kids observed	2.8 ± 6.5 (2.4)				1.8 ± 3.2 (1.1)	7.2 ± 5.2 (3.5)		4.7 ± 3.8 (1.7)
Kids:	2.6 ± 2.3 (1.8)				3.3 ± 5.3 (2.6)	9.3 ± 3.0 (2.2)		4.2 ± 3.7 (1.6)
Frequency in diet (%)								
Ewes	40	0	90	75	100	100	95	
Lambs	13				100	100	100	
Does	33	0	59	44	40	100		96
Kids	62				56	100		88
Percentage of diet by weight								
Ewes	0.4	0	0.5	0.6	7.1	15.2	1.1	
Lambs	0.1				37.4	20.2	5.0	
Does	1.1	0	0.4	0.3	0.4	5.2		1.1
Kids	0.4				3.4	10.3		1.9
Availability of plant								
Frequency in plots (%)	Not clipped separately	0	Not clipped	42	Not clipped	100	100	100
Phytomass (dry kg/ha)				1.6		20.9	24.3	25.7
% of all phytomass				1.0		5.9	7.1	5.5
Preference Index (% diet ÷ % availability)								
Ewes	?		?	0.6	?	2.6	0.2	
Lambs	?				?	3.4	0.7	
Does	?		?	0.3	?	0.9		0.2
Kids	?				?	1.7		0.3

* Significantly different from the value above at the .05 probability level.

When comparing this report to Griego's and to the biomass work presented in the earlier annual reports, note that the earlier research also classified the following species as annuals: Atractylis candida, Erodium glaucophyllum, Nolletia (or Inula) chrysocomoides, Plantago albicans, and Zollikoferia resedifolia. In section 13.4.2. of Progress Report No. 5, we followed previous researchers and called the above species annuals, except for N. chrysocomoides which was woody.

Standing dead and litter.-- Bites that were more brown than green were placed into this category rather than with their respective species.

Large amounts of nonwoody standing dead and litter, from phytomass grown since the previous falls' first rain, were available only during D2 and A (Table 10.17). The winter and spring pastures (B, C1, C2, and C3) involved a new year of growth, and as of the beginning of spring little vegetation had died or fallen to the ground. The biomass crews therefore did not measure gesh (standing dead and litter) during B and Begin C.

Sheep took more of their bites from standing dead and litter than did goats, in five periods significantly so (Table 10.17). The same result occurred in 1976 in C1 (13.4.2 of Progress Report No. 5). Preference for standing dead and litter was low when much palatable green vegetation was available in Begin D2, but standing dead and litter was preferred forage during End D2 and A when palatable green phytomass was scarce. Goats took a significantly larger proportion of their bites from standing dead than did sheep in pasture A and also at the end of C1 in 1976 (13.4.2 of Progress Report No. 5). However, sheep took significantly more of their bites than did goats from standing dead during End D2. Sheep always took more of their bites from litter than did goats.

The amount and composition of standing dead and litter ingested by livestock varied with the season and year. In C1 in July 1976 (13.4.2 of Progress Report No. 5), following much annual precipitation, only 8 percent of the ewe diet and 6 percent of the doe diet were of this category. The ewes ate mostly fallen seeds of H. spinosissimum while the does ingested mainly standing dead Z. resedifolia. At End C1 in early August 1976 (13.4.2 of Progress Report No. 5), 28 percent of the ewe diet and 25 percent of the doe diet were of standing dead and litter. The ewes ingested mainly fallen seeds of H. spinosissimum and L. pusillus, and the does fed on mostly standing dead L. pusillus.

At Begin D2 in mid-August 1976 (Table . .17), more green vegetation was available so only 13 and 3 percent, respectively, of the ewe and doe diets were composed of standing dead and litter, mostly of fallen seeds of A. uniflorum. By End D2 in late September 1976, little choice food remained among the green vegetation. Standing dead and litter comprised 61 percent of the availability, but contained few fallen seeds. Ninety percent of the ewe diet and 61 percent of the

Table 10.17

Preference for Standing Dead Combined with Litter by Sheep and Goats, August 1976 to April 1977

	Period of Observation in Relation to Flock's Entry into or Exit from Pasture							
	Begin D2	End D2	All of A	Begin B	End B	Begin C1	Begin C2	Begin C3
Percentage of bites ± SD(CI @ P = .05)								
Sheep: only ewes unless lamb rate stated below	9.3 ± 10.1 (3.0)	73.2 ± 13.7 (4.2)	36.7 ± 11.3 (3.6)	0.2 ± 0.9 (0.3)	0.6 ± 1.9 (0.6)	0.8 ± 1.7 (0.7)	0	
Goats: only does unless kid rate stated below	3.6* ± 4.6 (1.4)	33.0* ± 14.9 (4.6)	25.8* ± 12.6 (3.8)	0	0*	0*		0
Ewes: amount is under sheep if no lambs observed	7.5 ± 7.4 (2.8)				0.8 ± 2.2 (0.8)	0.9 ± 1.5 (1.0)	0	
Lambs:	12.8 ± 13.6 (7.5)				0.1 ± 0.5 (0.3)	0.8 ± 1.9 (1.3)	0	
Does: amount is under goats if no kids observed	2.7 ± 3.3 (1.2)				0	0		0
Kids:	5.5 ± 6.4 (3.9)				0	0		0
Frequency in diet (%)								
Ewes	80	100	100	8	18	36	0	
Lambs	87				7	18	0	
Does	67	100	100	0	0	0		0
Kids	69				0	0		0
Percentage of diet by weight								
Ewes	12.9	89.8	74.3	0.1	1.7	2.3	0	
Lambs	23.5				0.4	4.2	0	
Does	2.6	60.6	42.9	0	0	0		0
Kids	8.5				0	0		0
Availability of plant								
Frequency in plots (%)	100	100	100	The amount of phytomass which grew since September 1976 and later became standing dead or litter, was never measured.				
Phytomass (dry kg/ha)	589	362	392					
% of all phytomass	53.5	60.8	35.5					
Preference Index (% diet ÷ % availability)								
Ewes	0.2	1.5	2.1	?	?	?	?	
Lambs	0.4				?	?	?	
Does	Tr	1.0	1.2	?	?	?		?
Kids	0.2				?	?		?

* Significantly different from the value above at the .05 probability level.

doe diet were composed of standing dead and litter, primarily a great variety of recently dried forbs as well as annual grasses which had dried 3 months earlier.

In Pasture A in late October 1976, the standing dead and litter which the animals ingested again consisted of a great variety of nonwoody vegetative parts. As in End D2, few plants existed of the choice life-forms -- chamaephytes, hemicryptophytes, and therophytes. Furthermore, 24 percent of the availability in A was unpalatable *A. pungens*. Consequently standing dead and litter in A had preference indices of 2.1 for ewes and 1.2 for does.

With an abundance of highly palatable green vegetation, almost no litter was eaten during Begin B in mid-December 1976. By early February 1977 in End B only 67 kg/ha of green phytomass, mostly unpalatable, remained. Consequentlyonly 1 percent of the sheep diet was litter from the previous year. By late March and early April 1977 in C1, C2, and C3, an abundance of new green phytomass made it necessary to eat litter. Still, sheep ate from piles of flowers of *R. raetam* -- apparently they found the flowers highly palatable.

Although we never noticed animals eating litter until July in 1976, in 1977 they began ingesting litter by necessity in May. Furthermore, the "litter" was mostly high-quality seeds through August 1976. But by May 1977 animals, especially the sheep, were already beginning to eat stems which had grown during the 1975-76 agricultural year. We conclude that rainy 1975-76 provided an abundance of vegetation which stayed green well into the summer. When the animals began eating litter they could select from an abundance of high-quality seeds. In contrast, dry 1976-77 produced less phytomass, many fewer seeds, than did 1975-76, and the vegetation dried much earlier in 1977. Consequently by May 1977 the animals were already ingesting the stemy material from the previous year which they had refused during 1975-76.

Rankings of Relative Palatability

Overall, sheep appear to prefer the life-form categories in the following order, ranked from the most to the least preferred:

(1) Therophytes when individual plants are large (> 10 cm tall)
(2) Hemicryptophytes
(3) Chamaephytes
(4) Litter in the form of flowers and seeds
(5) Nanophanerophytes during the spring
(6) Therophytes when individual plants are small (under 2 cm tall)
(7) Geophytes
(8) Dead leafy parts of forbs and grasses
(9) Nanophanerophytes not during the spring
(10) Litter in the form of stems

Overall, goats seemingly prefer categories in the following order:

(1) Hemicryptophytes
(2) Chamaephytes
(3) Large therophytes
(4) Nanophanerophytes during the spring
(5) Litter in the form of seeds
(6) Dead leafy parts of forbs and grasses
(7) Geophytes
(8) Nanophanerophytes not during the spring
(9) Small therophytes
(10) Stemy litter

Of course variation exists between species within each category. Nanophanerophytes ranked low for both animals. If the woody parts of plants had been included in the availability estimates, the preferences for nanophanerophytes would have been even lower. The low preferences for nanophanerophytes probably contributes to the great abundance of the life-form.

When grazed together in the same pasture, goats feed more on taller plants and sheep feed more on shorter plants. Goats fed a great deal more than did sheep on nanophanerophytes, the tallest life-form, and somewhat more than did sheep on chamaephytes, the second tallest life-form. Sheep ate more than did goats of litter, therophytes, and hemicryptophytes -- the shortest life-forms. Sheep and goats ate similar amounts of standing dead phytomass and geophytes -- categories of intermediate height.

These differences in preference suggest that sheep grazing alone, and goats grazing alone might each alter vegetation composition in somewhat different directions; and give some basis for the project experiment which is testing this hypothesis. Time did not permit a detailed break-down of seasonal variations in preference and consumption for the purposes of this report. However, the analysis of this aspect is proceeding, and will be reported on in a subsequent report.

CHAPTER 11

BODY-WEIGHT TRENDS AND FECAL OUTPUT OF EWES AND DOES

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Introduction

Since a major project goal is to eluicidate the energy-flow pattern within the Chaabania ecosystem, it is necessary to calculate food consumption by animals, and how that food is partitioned among body growth and reproduction, metabolism, and ejestion of metabolic wastes and incompletely assimilated food. If through digestibility studies an animal's assimilation efficiency (i.e. the fraction of energy in its diet which it releases through digestion for its own use) can be determined, its total food intake can be calculated by dividing its fecal output by its assimilation efficiency. This is the approach reported on by Griego in Progress Report No. 3 and 4.

If in addition to an animal's food intake, its weight is known, food intake per unit of body weight can be calculated. By observing a large sample of animals, a general equation for food intake per unit of weight can be derived.

A simpler approach is to calcualate an animal's energetic requirements by using formulae, such as those of C.W.. Cook (Colorado State University Experiment Station Bulletin TB109, 1971). Such formulae employ several parameters, the most important of which is body weight. If one then knows the amount of metabolizable energy in the animal's food, one can calculate the amount of food consumed by the animal.

This chapter contains year-round data on body weights and a small amount of fecal output data for ewes and does. Griego's studies were restricted to male animals. The chapter does not address the question of digestibility or the energy content of the food.

Body Weights

Methods.-- Although weighing sometimes slightly delayed their departure for pasture, animals were usually weighed shortly before they reported from their shelters (grishas) for morning grazing. During the summer, animals were weighed just before the evening grazing period.

Results and discussion.--- Figure 11.1 depicts the body weights of ewes older than yearlings during most of a 3-year period. Because the project flock contained few yearlings during 1975-76 and none during 1974-75, yearlings were not included in the graph. If yearling ewes are included in the 1976-77 body weights of the project flock, they lower the

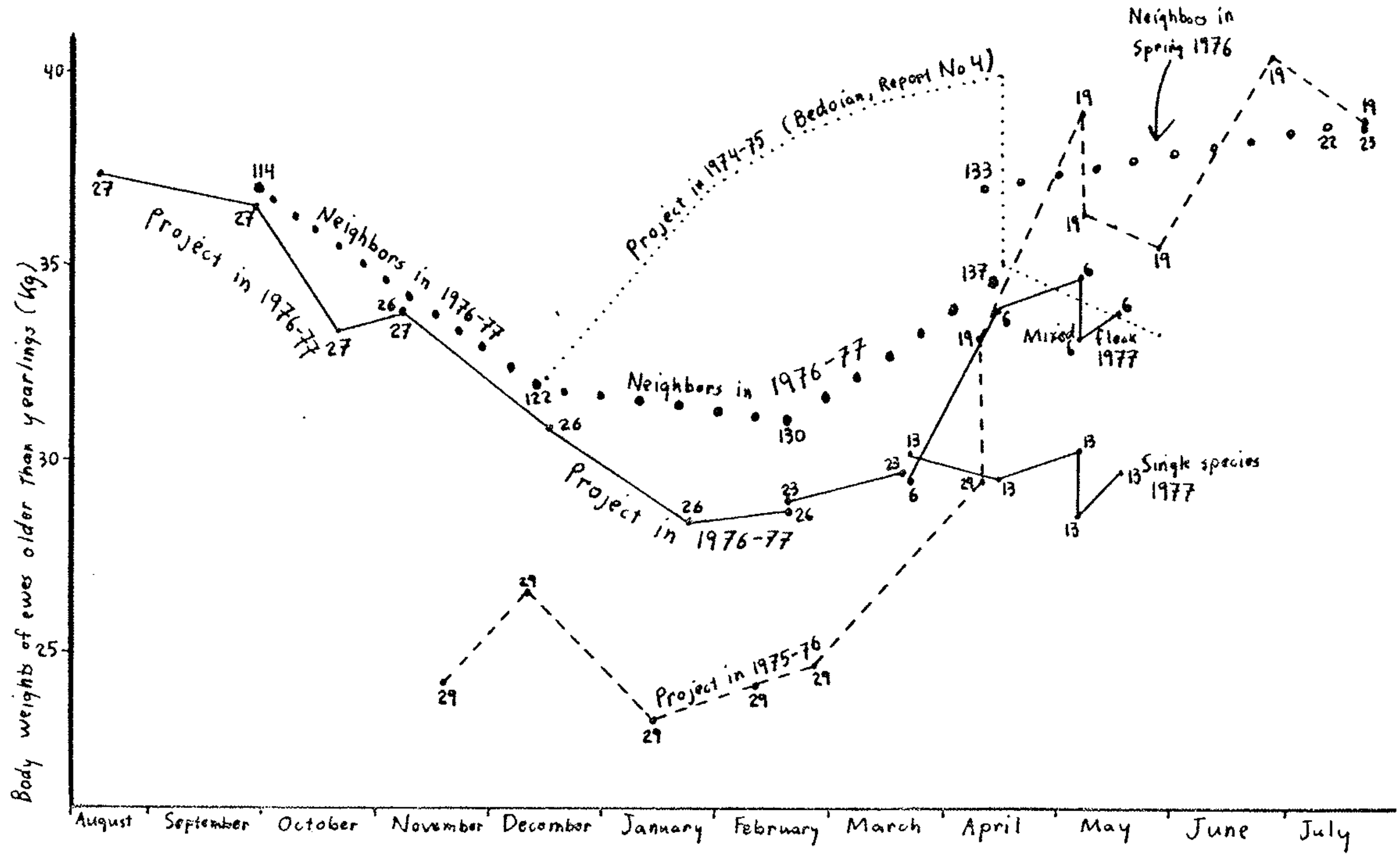

Figure 11.1. Weights of ewes older than yearlings. A new coterie begins each August.

average ewe weight by 4 kg in the fall and 2 kg in the spring.

Because the project flock contained few yearlings during 1974-75 and 1975-76, Figure 11.2 portrays the average body weights of project does older than yearlings during most of a 3-year period. If yearling does are included in the 1976-77 average weight of project does, they lower it by 4 kg in the fall and 3 kg in the spring.

When regarding the graphs, one should not be misled by the instantaneous rises and falls in average body weights caused by additions or deletions of animals. These changes are apparent if one notes the changes in numbers of animals observed. The sample sizes are recorded adjacent to the observation points on the graphs. Also, shearing of wool in May, 1977, reduced the weight of the 19 project ewes by an average of 1.6 kg (± .45 SD). This amount of wool was less than sheared in other years, possibly due to poorer nutrition.

Average body weights vary markedly from year to year (Figure 11.1 and 11.2). After taking into account the artifact of adding in a new coterie of 2-year old animals in August, ewes lost only 2 kg and does lost no weight in the project flock during summer 1976. The summer followed a year of excellent precipitation. On the other hand, the project animals apparently lost much more weight during summer 1975, but we unfortunately lack data from September 1975.

Winter growth rates of the project animals decreased during each successive year. Much of the change was probably due to decreasing forage per individual. From early December until mid-February the stocking rate was 135 adult days and 40 young days per ha in 1974-75, 237 adult days and 114 young days per ha in 1975-76, and 174 adult days and 117 young days per ha in 1976-77. Thus, even though more forage was present in 1975-76 than in the preceding year, the high stocking rate of 1975-76 probably lowered the growth rate. The project's stocking rate was somewhat lower in 1976-77 than in 1975-76, but it was evidently not enough to compensate for the much lower vegetative production in 1976-77.

We observed throughout the fall and winter of 1976-77 that the project animals received less forage than did neighboring animals: neighboring animals grazed much larger areas, and neighboring lambs and kids were supplemented with crushed barley. Thus neighboring ewes fare somewhat better than did project ewes (Figure 11.1). However, project does seemingly fared as well as neighboring does, probably because project does began the year heavier and included more older does. It remains to be seen whether the project management approaches will improve pastures sufficiently to allow animals to have better summer weight trends than the neighboring animals. On the other hand, more pasture and grain during winter allowed neighboring lambs to be marketed earlier and heavier, and for higher prices, than project lambs.

Ewe weights varied more between years than did doe weights (see Figure 11.1 and 11.2). Ewes also gained and lost weight faster than

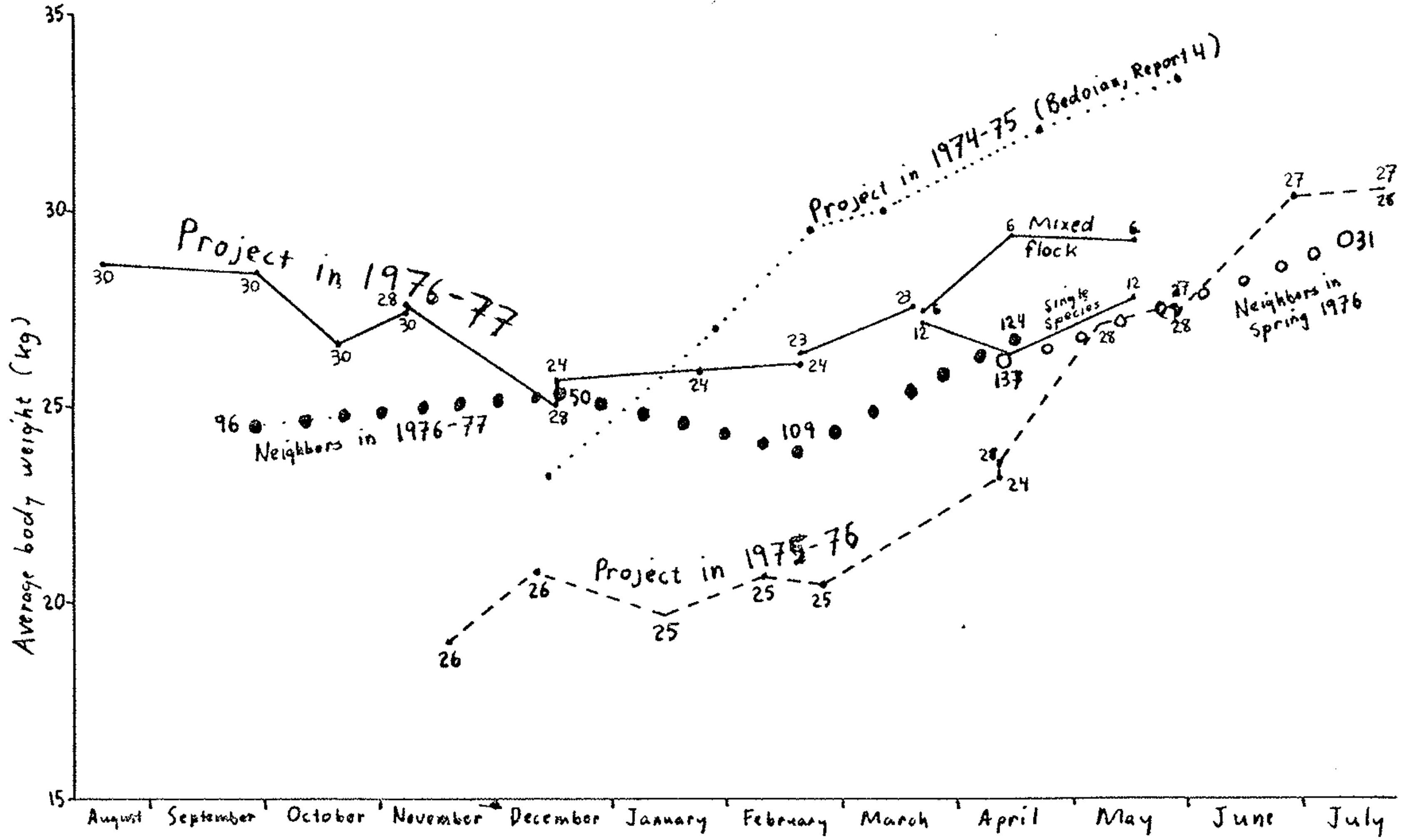

Figure 11.2. Weights of does older than yearlings. New coterie every August.

did does. These facts indicate that ewes are more susceptible to environmental change than are does.

Apparently lactation does not cause a ewe to expend much extra energy, at least when her lamb is older. Seven ewes older than yearlings had lambs which averaged 10.5 kg (± 2.7 SD). During the first 4 weeks in the sheep-only pasture (C2) in 1977, these ewes lost an average of 0.77 kg (± 1.49 SD). During this same period, eight ewes older than yearlings whose lambs had been recently weaned lost 0.88 kg (± 2.66 SD). Although the above results show that 10 kg lambs are not likely to affect their mothers' weights adversely, lambs are usually weaned at about 10 kg. In addition, a companion study indicated that nursing lambs over 10 kg gained weight during the period ($n=9$, $\bar{x}=89$ grams, SD=465), while weaned lambs over 10 kg lost weight ($n=7$, $\bar{x}=-700$ grams, SD=681). These means were different at $P<.05$.

Although similar studies should be performed over a longer period of time, this initial work suggests that prolonged nursing is not detrimental for the ewe and is advantageous for the lamb. Lambs can be allowed to suckle until they are sold or until the breeding season approaches and it is therefore desirable that the ewes no longer exhibit lactational anestrus.

Twin young did not seem to affect their mother any more adversely than did a single young. We compared the weights of females on 19 October 1976, before they gave birth, with their weights on 17 May 1977, when almost all of them were still lactating. Six ewes with twins lost an average of 4.9 kg (±2.2 SD) and 16 ewes with singles lost an average of 2.8 kg (±3.6 SD), but the difference was not significant. On the other hand, 11 does with twins lost an average of 0.1 kg (± 1.8 SD), while eight does with singles lost an average of 0.7 kg (±2.1 SD). After taking into account the fact that females lose more weight when giving birth to twins than when giving birth to singles, we conclude that supporting twins poses no more hardship on the females than supporting a single young.

Although Clun Forest ewes generally produce more milk if they have twins (Ewbank, Anim. Behav. 15:251-258, 1967), we hypothesize that nutritional limitations prevent females with twins from producing extra milk in southern Tunisia. We suspect that the milk production is completely utilized whether it is taken by one offspring or shared by two.

Still, it is advantageous to have some singles, because they can go to market earlier while the prices are higher. Singles can do this because they grow faster. Of course the early market can absorb only a certain number of animals; hence, the ideal may be to have some twins and some singles, as now occurs.

Fecal Collections

Introduction.-- We decided to study food intake only in ewes and does for several reasons. For one, Griego's earlier studies had involved only males. Most importantly, 93 percent of the adult sheep and goats in the project locals were females. Also, when counting only animals older than yearlings, males were larger than females: rams were 40% heavier than ewes and bucks were 70% heavier than does. In addition, we noted that rams and bucks often seemed to consume a larger proportion of their diets than did ewes and does from plants which allowed larger bites to be taken. Even within these plants, males appeared to ingest more stems. Such plants were *Retama raetam*, *Rhanterium suaveolens*, and *Lygaeum spartum*.

We first attempted to study intake by the weight balance method (Allden 1962 as cited by G.M. Van Dyne *In* Golley and Buechner (Eds.), *A Practical Guide to the Study of the Productivity of Large Herbivores*, 1968). With this method, animals are harnessed for complete collection of feces and urine and weighed just before and just after each grazing period. The method appeared ideal for our purposes, because animals near Chaabania are usually coralled when they are not actually grazing. The pilot study went well, but the urine collection bags soon developed leaks. We recommend the method to any future scientist studying food intake with the project, but with the qualification that more impervious materials be used.

The rest of this section concerns a standard, total fecal-collection study.

Method.-- Canvas fecal collection bags were fit to adult females 12 days before the actual study began. The harnesses and bags were arranged so that the animals' behavior was not altered, and so that no feces escaped. The bags allowed some urine to pass through.

The animals began feeding in Pasture C1 on the morning of 20 March, 1977. The study began with emptying the bags and deharnessing watering, weighing, and reharnessing the animals between 8 and 9 am, on 23 March for the ewes and on 24 March for the does. After this, all feces collected from any one animal within any 1 day were boxed together and oven dried. If for some reason feces were lost, that day's collections for that animal were discarded. Between 8 and 9 am on 31 March, the end of the study, the animals were deharnessed, watered, and weighed.

Results and discussion.-- Table 11.1 shows the results of the fecal collection study. The three ewes under observation egested similar amounts of feces daily per unit of body weight $^{3/4}$, averaging 42.6 (± 0.6 SD) grams/kg$^{3/4}$/day. The three does varied more: 42.8, 39.7, and 29.4 grams/kg$^{3/4}$/day. Although some of the small difference between the ewes was correlated with weight gain (r^2=.43), a large amount of the doe difference was correlated with weight gain (r^2=.72). The slowest growing doe, which egested the least feces, had aborted 3 days before the study began. The other females studied had previously ceased nursing their young.

Table 11.1

Fecal Collections Obtained from the Beginning[1] of Pasture C1 in 1977

Animal Type	Ewe	Ewe	Ewe	Doe	Doe	Doe
Ear-tag Number	27	23	13	48	67	51
Av. Body Weight (kg)[2]	29.8	33.0	35.3	24.9	28.5	31.2
Av. Weight Less Wool	27.7	31.5	33.2			
Weight Gain per Day (grams)[2]	310	250	340	140	30	60
Number of Days Observed	7	8	8	5	6	7
Feces per Day (ovendry grams)	521	558	589	477	363	524
± SD of Feces per Day	51	81	44	27	13	46
± CI @ .95 pf Feces per Day	48	68	37	33	14	42
Grams of Feces/Kg Body Wt./Day	17.5	16.9	16.7	19.2	12.7	16.8
Grams of Feces/Kg Body Wt. Less Wool/Day	18.8	17.7	17.7			
Grams of Feces/(Kg of Body without Wool)$^{.75}$/Day	43.2	42.0	42.6	42.8	29.4	39.7

[1] The animals entered C1, which had relatively abundant forage, early on 20 March 1977. They had previously been on a very poor pasture. The animals had been bagged since 12 March. The study began on 23 March for ewes and 24 March for does.

[2] The animals were weighed following watering before pasturing at both the beginning and end of the collection period.

In our opinion, the estimates of daily fecal output during the dietary composition observations in pasture C1 are reasonably good. Unfortunately, this was only one of eight dietary observation periods. We had not the time to collect feces during the other periods. Still one could estimate energetic requirements for each period from formulae. These formulae could be tested by comparing the amount of food intake necessary, during the beginning of C1, as estimated by the metabolizable energy and the formulae on energy needs, and as estimated by the digestibility and total fecal collections.

CHAPTER 12

SHEEP AND GOAT DEMOGRAPHY

by D. Coleman Crocker-Bedford
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Introduction and Methods

The number of offspring reaching marketable age per doe or ewe present is an important component of the secondary productivity of the PreSaharan ecosystem. This component can be separated into the number of viable young per female with viable young and into the proportion of females producing viable young. The age and reproductive status of each female in the project flock and in several neighboring flocks were observed on several dates.

Age classes were based upon the number of adult incisors present: from 0.5-year of age until the first adult incisors erupted sheep were classified as barkoussa and goats were classified as berchnias; when two adult incisors were present sheep were houlya and goats were jedaa; when four adult incisors were present both animals were rebaya; when six adult incisors were present both animals were sedasse; after all eight adult incisors erupted both animals were jamaa; after the adult incisors were very worn and sometimes missing both animals were cherf.

Technicians observed the number of young present with each female, and verified with the flock owner that the young were the female's. Flock owners also stated whether any of a female's offspring of the present agricultural year had already left the flock. Young present in mid-April, or traded or sold or eaten before mid-April, were considered to be viable offspring. Thus the number of viable offspring does not include those young which died at an early age, but it does include the few young, always singles, which were utilized before mid-April. The reported numbers of marketed, traded, or eaten young were verified to be accurate by comparing the February census to the April census.

Unlike in our previous annual report, here we do not count the few pregnancies of mid-April as viable offspring. We have two reasons: the diagnoses of pregnancies were often inaccurate, and young born after mid-April are not economically beneficial because they require much grain. We wish also to note that the numbers of estruses listed for April 1976 in our previous annual report were inaccurate -- we had mistranslated an arabic word.

The project flock and seven neighboring flocks were observed between 9 and 12 April 1976. The same eight flocks were observed on 12 and 13 April 1977. The project flock and six of the neighboring flocks were also observed on 28-29 September and 15-16 December 1976 and 16-18 February 1977.

Results

For the neighboring flocks, the number of viable lambs per reproducing ewe (a ewe with viable young) was 1.09 in 1974-75 (Bedoian and Bedoian, Table 13.10, Report No. 4), 1.04 in 1975-76 and 1.18 in 1976-77 (Table 12.1). Combining data for all reproducing ewes of both the project and the neighbors indicates that the viable lambs per reproducing ewe increased significantly (X^2=11.5, df=1, P<.005) between 1975-76 and 1976-77, from 1.05 to 1.19. Since the number of viable lambs per reproducing ewe of the combined April 1976 and April 1977 project and neighboring ewes did not vary with the age of the ewe (X^2=1.51, df=5, P=.90), the differences in the twinning rates between years probably were not due to shifts in age composition. Combining the data of 1975-76 and 1976-77 gives a project average of 1.18 lambs per reproducing ewe, while the neighbors averaged only 1.12 lambs per reproducing ewe, but the difference was not statistically significant (X^2=1.08, df=1, P<.5).

For the neighboring flocks, the number of viable kids per reproducing doe was 1.18 in 1974-75 (Bedoian and Bedoian, Table 13.10 of Report No. 4), 1.21 in 1975-76, and 1.24 in 1976-77 (Table 12.2). After combining the data from April 1976 and April 1977 and from both project and neighboring flocks, the number of viable kids per reproducing doe varied significantly with the age of the doe (X^2=19.4, df=5, P<.005). Combining project and neighboring animals, but using each age class as a separate group in a chi-square analysis, shows that the number of viable kids per reproducing doe was similar in 1975-76 and 1976-77 (X^2=4.1, df=11, P=.95). Combining both years, but using each age class as a separate group in a chi-square analysis, indicates that the number of viable kids per reproducing doe was similar for the project and neighboring does (X^2=4.0, df=11, P=.95).

Table 12.3 shows the number of viable young produced per female, including females without young. This rate equals the number of viable young per reproducing female (see Tables 12.1 and 12.2) multiplied by the proportion of females which produce viable young. For neighboring animals, viable lambs per each April ewe averaged 0.87, 0.66 and 0.84 in 1974-75, 1975-76, and 1976-77, respectively. Unlike the twinning rate, the number of viable lambs per ewe was higher for older ewes, indicating that fewer young ewes bore viable young. The project flock produced more lambs per ewe than did neighboring flocks. In 1976-77, birth rates per April ewe were higher than the rates per September ewe: 35 percent higher for the project and 24 percent higher for the neighbors.

Viable kids per neighboring April doe, including barren does, averaged 1.23, 1.08, and 1.26 in the years 1974-75, 1975-76, and 1976-77, respectively. Older does not only produced more twins per reproducing doe than did yearlings, but more older does reproduced. For does at least 2-years old, the project flock produced fewer young per doe than did neighboring flocks in 1975-76, but more than the neighbors in 1976-77. In 1976-77, the birth rates per April doe were higher than the rates per September doe: 31 percent greater for the project and 12 percent higher for the neighbors.

Table 12.1

Number of Viable Lambs per Reproducing Ewe

Age and Owner of Mother	No. of Ewes with Viable Lambs		No. Viable Lambs per Ewe with Viable Young	
	April 1976	April 1977	April 1976	April 1977
Barkoussa				
Project	1	1	1.00	2.00
Neighbors	11	8	1.09	1.13
Houlya				
Project	7	8	1.00	1.13
Neighbors	8	43	1.00	1.23
Rebaya				
Project	6	5	1.17	1.40
Neighbors	29	29	1.00	1.21
Sedasse				
Project	8	4	1.00	1.25
Neighbors	46	33	1.04	1.24
Jamaa				
Project	4	9	1.25	1.22
Neighbors	17	32	1.12	1.13
Cherf				
Project	0	4		1.25
Neighbors	1	16	1.00	1.00
All ages				
Project	26	31	1.08	1.26
Neighbors	112	161	1.04	1.18
Rebaya or older (at least 2-years)				
Project	18	22	1.11	1.27
Neighbors	93	110	1.04	1.16

Table 12.2

Number of Viable Kids per Reproductory Doe

Age and Owner of Mother	No. Does with Viable Kids		No.Viable Kids per Doe with Viable Young	
	April 1976	April 1977	April 1976	April 1977
Berchnias				
Project	0	0		
Neighbors	7	6	1.00	1.00
Jedaa				
Project	8	1	1.13	1.00
Neighbors	12	37	1.00	1.08
Rebaya				
Project	5	0	1.20	
Neighbors	35	27	1.26	1.19
Sedasse				
Project	2	9	1.00	1.44
Neighbors	26	31	1.15	1.35
Jamaa				
Project	1	11	2.00	1.64
Neighbors	23	26	1.30	1.31
Cherf				
Project	1	4	1.00	1.50
Neighbors	10	12	1.40	1.50
All ages				
Project	17	25	1.18	1.52
Neighbors	113	139	1.21	1.24
Rebaya or older (at least 2-years old)				
Project	9	24	1.22	1.54
Neighbors	94	96	1.26	1.31

Table 12.3

Number of Viable Young Produced per Female, Including Females Without Young

Age, Species and Ownership	1974-75 Agricultural Year[1]			1975-76 Agricultural Year			1976-77 Agricultural Year				
	Viable Young by Apr.	Ad.♀♀ Present in Apr.	Young per Apr. ♀	Viable Young Apr.	Ad. ♀♀ Present in Apr.	Young per Apr. ♀	Viable Young Apr.	Ad. ♀♀ Present in Apr.	Young per Apr. ♀	Ad. ♀♀ Present in Sept.	Yg. per Sept.♀
All Females, Including Yearlings											
Sheep											
Project				28	40	0.70	39	31	1.26	42	0.93
Neighbors	78	90	0.87	117	177	0.66	190	183	1.04	226[2]	0.84
Goats											
Project				20	24	0.83	38	33	1.15	43	0.88
Neighbors	84	85	0.99	137	190	0.72	172	186	0.92	209[2]	0.82
Females at Least 2 Years Old by Apr.[3]											
Sheep											
Project				20	22	0.91	32	23	1.39	28	1.14
Neighbors	76	70	1.09	97	112	0.87	128	113	1.13	125[2]	1.02
Goats											
Project				11	13	0.85	37	23	1.61	30	1.23
Neighbors	76	62	1.23	118	109	1.08	126	100	1.26	117[2]	1.08

1 Data from Bedoian and Bedoian (Progress Report No. 4). We assume that their yearling mothers produced only singles.

2 One flock, not measured in September, was assumed to be larger by the same proportion as the other six flocks.

3 By dental age, these animals were at least rebaya in April. Two year olds which were still houlya or jedaa were excluded from this group because they could not be distinguished from yearlings.

Discussion

Except for differences induced by changes in age structure or percentages of adults culled prior to April, we assume that the productivity differences between the animals in different years, and between the project females and the neighboring females, were due to nutritional differences. A larger proportion of older ewes and does produce viable offspring than do younger ewes and does, and older does are significantly more likely to twin than are younger does. On the other hand, the incidence of twinning does not vary with the age of reproducing ewes.

Ewe productivity is more susceptible to environmental variation than is doe productivity. The ewe twinning rate varied significantly between years, but it remained similar for does. Likewise, the twinning rate was slightly higher, though insignificantly so, for project ewes than for neighboring ewes; but the doe twinning rate was similar for the project and the neighbors.

It is difficult to compare the proportions of animals giving birth because they are strongly affected by the culling of females. During 1976-77, the project culled many more infertile and post-lactating females than did the neighbors, which caused a great apparent divergence in the proportions of animals giving birth. On the other hand, neighbors culled more females prior to mid-April, 1976, than did the project. Without such culling, the proportions of females that reproduce would have been more similar.

Differences in culling may also account for the apparently low production per female, including barren females, in 1975-76. We know that no project females were sold between October 1975 and April 1976, and we hypothesize that the neighbors also may have culled fewer females than normal, owing to the unusually large amount of rainfall. Thus an unusual number of barren females would have been present in the April census.

These problems with selling may be partially circumvented by regarding the number of viable young produced per September female; however, we have data for only 1976-77. For the females present in September which would have been at least 2-years old by April, project ewes produced 12% more lambs per ewe than did neighboring ewes, and project does produced 14% more kids than did neighboring does. Three-fourths of the greater production by project ewes was due to a greater twinning rate, and only one-fourth was due to more ewes lambing. The doe productivity difference was confounded by different age structures.

Although the project attempted to maintain the same age distribution as that of the neighboring animals, the tables indicate a lack of success. The problems involved misaging, age-class advancement, and difficulties in purchasing animals.

Even though the personnel aging the animals definitely understood the method, they often made mistakes because of the speed with which they worked. While we were careful not too vertly criticize their work we were able in a few instances to tactfully age the animals ourselves. But we were never entirely able to rectify the problem.

Advancement in dental age occurred primarily between March and May for most age classes, but it could occur in almost any month. Different flocks advanced at different times too. Thus one chronological age could often be found in two dental age classes.

The other age structure problem concerned buying animals. When the project sought an animal of a specific dental age, it almost invariably acquired one which was soon to enter the next age class.

CHAPTER 13

EFFECTS OF RURAC-URBAN MIGRATION ON A PRESAHARAN COMMUNITY

by Concepcion E. Lee

Introduction

The impact of the culture and its land use on the Chahbania ecosystem is not a static one. The local population is increasing, and its technology is changing with altered economic patterns. Hence, in the course of pursuing the project objective of understanding the human effects on the system, and devising alternate, ecologically sound land-use patterns, it becomes important to assess how the effects are changing and why.

In a self-contained system,human populations and their extraction of sustenance from the system are ultimately limited by the resources and environmental constraints of the locale. Permanent or temporary emigration can alter the pressures on the system. If permanent, emigration can provide the output which avoids build-up to excessive population levels. But if only temporary -- as in the case of short-term wage labor in more affluent urban areas -- the resources brought home can supplement those extracted locally from the ecosystem. Such supplementation can enable populations to increase beyond the in situ carrying capacity of the system. In the process, pressures on the system may be sharply increased, as with technologically more efficient exploitation of the land (see Chapter 18 by Bedoian), and if domestic animal numbers grow as a function of increased population growth. Hence a knowledge of migration patterns becomes valuable in predicting the trends in ecological impact by the culture.

The goals of the present study are to determine, through an intensive study of the Chahbania area and economy, those factors influential in causing migratory movements out of this area and to examine the effects-- social, economic and political-- that this migration has on the economy and ecology of the region.

The unit of analysis used in this study is the rural sector of Chahbania (formerly called cheikhat) (Figure 14.1) with a total population of 3733 (census of 1975) of which 103 individuals live in the village of Chahbania proper. This rural sector is under the jurisdiction of the ommda (mayor or administrative officer) of Chahbania and covers an area of 970 km^2. Population density of the sector is 3.84 persons per km^2. The sector is located in the Gouvernorat of Medenine with a total area of 66,920 km^2 and a mean population density of 6.1/km^2.

The village of Chahbania is the primary center of attraction for people distributed over a fairly wide area who depend on this small center for satisfaction of bureaucratic, commercial, educational, and medical needs.

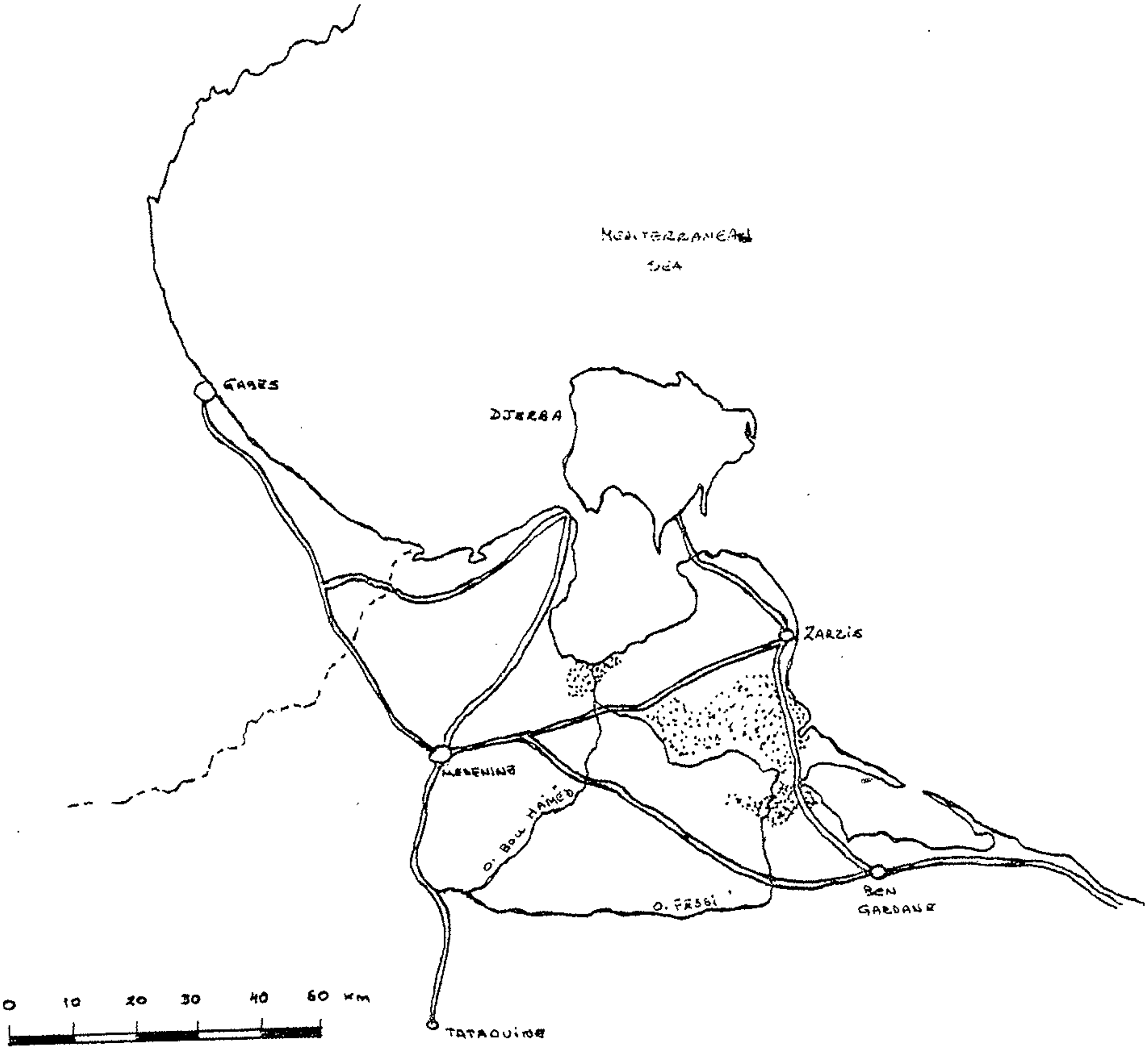

Figure 13.1. Map of southeastern Tunisian area within the Djeffara. The dotted region is the rural sector in which sampling is taking place.

Corrigendenum:

On p. 191, the legend for Figure 13.1 states that "The dotted region is the rural sector in which sampling is taking place." In fact, the rural sector is the four-sided area bounded by a thin, solid line; and of which the Oued Bou Hamed and the Oued Feggi form the western and southern boundaries. The dotted regions are the salt flats along the coast.

Social interaction is based primarily on kin groups and is by and large included within the boundaries of the rural sector. Spill-over into adjoining areas does occur concomitantly with the contination of kindred groups in adjacent areas.

Economic activity on the other hand, extends over a much wider area. This is of necessity so in an area of limited exploitable resources and job opportunities. Migration is one form of adjustment or strategy to overcome economic limitations.

Since January 1977 through mid-August 1977 this study has gathered data along the following lines:

(1) Demographic information: Family composition in the rural sector; age, sex, education, occupation, and residential patterns; population mobility; demographic alterations due to marriage and out-migration.

(2) Patterns of land tenure and land utilization: Methods of land acquisition (sales, inheritance, other methods of gaining access to land, both temporary and permanent); agricultural exploitation (olive and fruit tree cultivation and production, cereal production); utilization of communal lands; utilization of lands for grazing; land-use strategies in both private and communal lands that are adapted to climatic variations.

(3) Techniques of production: Technology employed in agricultural and livestock production; time/labor costs of agricultural and livestock production.

(4) Family economics: Production and consumption patterns; sales of production and investments; cash needs; employment patterns and income utilization.

(5) Marketing: Study of livestock sales, volume and timing; grain and olive sales; survey of consumer goods sales and provenance of these goods.

Methods

Data are being collected in the Chahbania area utilizing interview techniques and questionnaires administered primarily during the first 4 months of work with re-visits for additional data during May and June. More traditional anthropological tehniques such as participant observation are an intrinsic part of this study also. Participant observation allows for gathering data of a multidimensional nature which means that the social context within which a phenomenon is being observed is delineated sharply by being in continuous interaction with members of a community. Since the goals of this project are in part those of assessing the effects of migration on the social personnel left in the community, such tehniques are an essential counterpart to the formal interviews and questionnaires.

This is particularly important in the investigation of family economics where overall production and consumption patterns do not vary widely but where observation and interaction indicate differences in the economic aspirations and expectations between families.

Additional data are being gathered via a questionnaire administered only to women for the purpose of elucidating work and social activity patterns and network formation. These will yield additional insights into modes and techniques of production as well as social data such as depth, strength and flexibility of the kin groups as primary support systems and changes in interaction patterns with economic change. This questionnaire also includes questions on social events such as circumcisions, weddings, and religious events which indicate additional areas of cash utlilization and perceived cash needs.

Interviews with both men and women have been gathered to build an in-depth picture of the Chahbania area, ecologically, economically and socially. These interviews also give an indication of alternatives and choices open to individuals in the past contrasted to perceived alternatives today.

Weekly observations of the Chahbania market and inventory of livestock, grain, olive, and wool sales give information on changes in the weekly market during the agricultural year.

Results

Since data are still being gathered and analysed at this time, the results presented here are only a partial summary of some of the information that has been gathered and analyzed to date.

This study has obtained 66 major interviews where the economic/social questionnaire has been administered. The population represented in these interviews is 15% of the total population of the rural sector. Of this population, 490 (13.9% of total population in the sector) constitute the core of families residing under the head of household, 77 individuals are collaterals on whom marriage, occupation and residential pattern information has been obtained.

Interviews with women number 28 of whom 19 are also included in the economic/social interviews thus yielding a more complete picture of family social and economic acitivty.

The population sampled belongs to 20 different family groups with strong (32) representation of two family groups which correspond to the dominant lineages in the Chahbania area.

Of the population cited above, 65 individuals are considered migrants (27.9% of the male population). Under this category are included those individuals who are working abroad (France and Libya) as well as those individuals who are not working within the rural sector of Chahbania. Additional data on migration are presented below.

Of the 490 individuals who form the core sample, 233 are men and 257 are women. These include only two generations, and offspring of the second generation are for the moment not being considered here. This sample may still under-represent women, this will be corrected once the genealogical and residential information has been fully analyzed.

The education for these individuals is distributed as follows:

7.0% have some degree of secondary school education
24.2% have some degree of elementary school education
40.8% are illiterate women
20.7% are illiterate men
7.3% (men only) have attended Koranic school
A small number of children are under school age

This sample accounts for a total of 2,657 ha owned by individuals residing in the rural sector. It includes communal land wherever the number of hectares held per family or individual are known as well as a small number of hectares held outside the Chahbania area.

A total of 8,639 olive trees are reported (13% of land holdings) and of these 34.6% are young trees that do not yet bear fruit.

Fruit trees, predominantly figs, total 2,300. The total number of hectares under olive and fruit tree cultivation in the rural sector is 392 ha (14,75% of land held).

The land under cereal cultivation covers 328 ha (12.34% of land held). This figure reflects the total for the agricultural year 1975-1976 which, due to an extraordinary amount of rainfall (497 mm cited in Progress Report for 1976, p. 13) resulted in a maximum amount of land cultivated in contrast to the poorer year 1976-77.

The total available grazing land would be calculated at 1,937 ha or 72.90% of the amount of land reported. Given the lack of accuracy in the reports of communal lands to which most people have access, this percentage ought to be higher. The final analysis of communal land holdings has not yet been done.

The economic system is being analyzed in terms of three basic components: (1) resource availability, (2) techniques employed in production, (3) organization of human personnel.

Examination of the natural resources available to people, and access to new resources is the starting point in an investigation of how the human utilization of the environment influences and changes it as well as how environmental limitations constrain and alter existing social groups.

Techniques of production are considered since it is through the use of specific techniques that a group can exploit any given set of resources more or less efficiently. Techniques, therefore, in conjunction with particular features of human organization constitute the structural economic base line. Techniques also define the capacity to change or alter the environment more or less rapidly.

The organization of human personnel gives us insight into the patterns of behavior developed in the face of environmental and social limitations. These patterns of behavior can be understood as adaptations (defined in terms of goal satisfaction) or strategies that have repercussions on the economy of the Chahbania area but that also influence and are influenced by "culturally styled needs and wants" (Bennett:11).

These three basic components will ultimately be placed in a wider regional perspective to appraise the direction and magnitude of economic, social and cultural changes of this area in the context of the arid zone of which it is a part.

The sample obtained has been divided into eight types defined by the primary source(s) of income and the number of men in each sample who are wage earners. The typology considers, of course, only Chahbania rural sector residents. The men, though working elsewhere, have their families in Chahbania, and are considered to be residents of Chahbania in the national population census.

The following is a summary of the main characteristics of each type:

(1) Agricultural producers only: One resident adult male, head of household, who works exclusively in the agricultural sector without an alternative source of income.

(2) Employed in Chahbania: One resident adult male, head of household employed full-time in a salaried occupation in Chahbania.

(3) Employed outside Chahbania: One resident adult male, head of household employed full-time in a salaried occupation outside the Chahbania rural sector, but not abroad. This type is constituted primarily of individuals working within the Gouvernorat of Medenine.

(4) Agricultural producer and employed in Chahbania: Two or more males residents of a household one of whom will be engaged in agricultural work only (usually the eldest male), the other(s) working as salaried workers within the Chahbania rural sector.

(5) Agricultural producer and employed outside Chahbania: Two or more male residents of a household one of whom will be engaged in agricultural work only, as in Category 4, the other(s) working as salaried workers outside the Chahbania sector.

(6) Agricultural producer and migrant abroad: Two or more male residents of a household, at least one of whom will be engaged in agricultural work and one working as a migrant abroad.

(7) Agricultural producer, migrant abroad and employed in Chahbania: Three or more male residents of a household. The families in this category have at least one member employed in each of the above sectors.

(8) Agricultural producer, migrant abroad and employed outside Chahbania: Three or more male residents of a household. The families in this category have at least one member employed in each of the above sectors.

The samples that constitute each type have thus far been examined for information on land resources, agricultural production, livestock holdings and animal sales, average incomes, and land investiments. Since a full analysis of the data has not been completed, I can only offer here some tentative generalizations based on the raw figures compiled to date.

Type 1 (agricultural producers only) individuals emerge as the strongest agricultural producers, as would be expected for individuals whose sole mode of subsistence is agriculture. This category is constituted of individuals that are old heads of household that have very limited manpower due to separation of sons from the extended family, or else are middle-aged individuals who lack manpower due to the youth of their dependent children.

In contrast, Types 7 and 8 are wealthiest in terms of resources available and utilized; they have the highest cash incomes and are the highest investors in land. These two groups are at a point in the family developmental cycle where the most economic alternatives can be tapped. They are effective agricultural producers and meet cash needs with at least one migrant abroad and one employed in the area. It can be said judging from the group's investments in land and young olive trees, that these individuals have chosen to remain on the land and continue exploiting it.

Type 4 finishes the top rank as secure in its resources and beginning its diversification and extension into other areas of resource utilization and cash employment. At the same time, this group may be a disintegrating one because, though relatively wealthy right now in terms of land and animals, the younger men in this group have manifested wishes definitely to leave the area and work elsewhere, outside of the agricultural sector.

Types 6,3 and 5 form the middle range of the scale. This group as a whole is concentrated in Chahbania village and its immediate outlying area. Its personnel is quite important in terms of social prestige. The three types combined have the highest number of educated technicians earning high incomes. The potential for long range investments and change in this group as a whole is quite high.

The last, Type 2, is the least wealthy both in terms of resources (land, trees, animals) and in terms of earning potential. Individuals in this group are also constrained by manpower possibilities. However, this group has changed considerably in the last 5 years. If it is today the poorest, one can only speculate what its condition would be in the absence of two factors: the Desert Biome and the ex-ommda's entrepreneurial activities. Of the 11 families that constitute this type, 5 are project employees and 3 are employees of the ommda, 3 others are independently employed. All the individuals in this group are illiterate or functional illiterates (2 attended Koranic school) with only one exception (6th primary completed), so that their alternatives outside the Chahbania system seem quite limited.

Data on manpower and technology has not yet been analyzed and will undoubtedly add to our view of each group as more or less effective producers and changers of the environment.

A more accurate model than can be obtained at this time will be worked on and refined as more information is gathered and assimilated. I would wish to emphasize that in speaking of the trends and potential for change in the Djeffara area, culturally directed sanctions and goals must be analyzed jointly with economic data and carefully examined for long-range implications. The Chahbania rural sector is at a stage in its developmental cycle where, due to its particular age and educational features, change may be possible in the realms of more efficient and less environmentally deleterious methods of agricultural production and livestock raising. If a "managerial style" seems lacking in the data thus far examined, it points to the need for demonstration and education in these areas, without which regional development is unlikely.

Acknowledgments

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PART IV

TOWARD SYNTHESIS

CHAPTER 14

ESTIMATES OF TOTAL MACRO-ARTHROPOD BIOMASS

by R. J. Muir

Introduction

The eventual goal of elucidating energy flow in the arthropod component of the Chaabania ecosystem depends on the synthesis of several field and laboratory approaches. An important starting point is the estimation of arthropod populations in the field. Methods used to sample specific groups such as ants, large beetles, and transient large species lead fairly direclty to estimates of numbers and, with weighing, to estimates of biomass.

Two more general methods require considerably more analytic time. The sweep method mainly samples flying insects and those arthropods loosely attached to vegetation. The cage method samples arthropods flying close to, attached to, or parasitic on, the foliage of perennial shrubs. It also samples arthropods on the ground surface close to perennial shrubs and those beneath the ground surface associated with the roots of the perennial shrubs. The two methods are complementary, and both sample hundreds of species at varying densities. Four seasonal samples in each of 3 years in six different soil-type sampling areas by both methods have amassed a considerable amount of material.

In order to process the material obtained with these latter two methods for biomass and energy-flow calculations, the samples must first be subjected to the time-consuming procedures of sorting, identification, assignment of trophic function, drying, and weighing. For the sweep method, assignment of trophic status depends on a knowledge of the feeding predilections of each species because it only leads to estimates of the arthropod fauna in defined areas without close reference to the plants which the animals use. The cage method, however, in sampling arthropods associated with specific perennials, can yield plant specificity, trophic level, and specializations of the sampled species as they are extracted individually from their micro-habitat.

Ideally, calculations of energy flow depend on a knowledge of the species' demography and bioenergetics, and to this end demographic and respirometric studies have been carried out on a number of the more important species. But with an arthropod fauna numbering on the order of 1,000 species, such studies are obviously impossible for all or most species within the existing constraints of time and resources. Eventual calculations will depend on one or more of the available, general equations for food consumption or metabolic rate as functions of animal size and environmental temperature.

At the time of this writing, a major amount of sorting, identification, assignment of trophic status, and weighing still remains to be done before food-consumption and metabolic calculations can be made. However, for very preliminary purposes at this stage, it is perhaps of interest to calculate total biomass by trophic level for two of the sampling areas over a 2-year period.

Methods

Total arthropod biomass was estimated from the non-grazed area (Area 1-3) in the Dar ez Zaoui site and for the heavily grazed area (Area 6) outside the Dar ez Zaoui site for 1975 and 1976. The data to be presented below were derived from methods described in previous chapters and progress reports on the beetle and ant studies, and the above- and below-ground cage-sampling method. Data from the sweep method are not included because the samples still remain to be sorted. For this reason, the estimates presented below will be low, and final ones will need to be adjusted upward to take into account the sweep-sample species.

The cage method is based on ten randomly selected perennial shrubs for each sample. The cage, a meter high and covering a surface area of half a square meter, is worn by the investigator. It is quickly placed over each shrub and the base is sealed with sand to prevent escape of arthropods. All macro-arthropods associated with each shrub, above ground, on the ground surface, below ground to a depth of 25 mm, and within the tissue of the shrub are collected in the field and the laboratory. Above-ground standing crop of each perennial shrub sampled, is dried and weighed to give a relationship of numbers of arthropods per unit dry weight of perennial shrub. Plant biomass studies taken at the same time as arthropod samples yield standing-crop dry weight per hectare of perennial shrubs and hence numbers of arthropods per hectare may be calculated.

To estimate arthropod biomass per hectare, dry-weight values must be assigned for each species. For the more common and larger species, dry weights were determined directly by oven drying and weighing samples of each species. For less common species, dry weights were assigned indirectly by extrapolation from body-length/dry-weight regressions.. Body length was recorded routinely at the initial capture and cataloguing of each species. For each major taxonomic group and for non-taxonomic, morphologicaly based groups (e.g. larvae) regression curves were constructed from samples of each group of varying body lengths.

Assignment of species to trophic-level categories of herbivore, detritivore and carnivore, cannot be highly accurate until identification of species has been obtained. For this report, adults and different growth stages of each species have been assigned to trophic levels from observations of trophic behavior, knowledge of trophic habits of their taxonomic group (e.g. Order, Family, Sub-family) and from knowledge of micro-habitat as recorded in cage sampling. For those species with a mixed diet, a scale of 10 was given and an estimate was made to assign the proportion of trophic habit (e.g. 6 carnivore, 4 detritivore or 8 detritivore, 2 herbivore). Thus the biomass of a species was assigned to trophic levels according to its estimated diet proportion.

Results

Table 14.1 shows the contribution to biomass results from the four sample methods used: ant biomass, large-beetle biomass, above-ground cage biomass, and below-ground cage biomass.

Over the 2 years' records of seasonal biomass samples, there was little difference between the total biomass estimates for Areas 1-3 and 6 with Area 1-3 biomass (52,243 g/ha) slightly exceeding that of Area 6 (49,903 g/ha). Total ant and large-beetle biomass records are of a similar magnitude between the two areas, with Area 1-3 again exceeding Area 6 in total biomass values. Cage results were quite different for the two areas. Total above-ground biomass in Area 1-3 exceeded that of Area 6 by over 10,000 g/ha, while total below-ground biomass of Area 6 exceeded that of Area 1-3 by over 10,000 g/ha. This can be explained by the predominance of above-ground herbivores in Area 1-3 and below-ground detritivores in Area 6 (see discussion).

Generally, with each cage area, cage below-ground biomass made the highest contribution to total biomass. Ant biomass was generally greater than that of large Coleoptera. Above-ground cage biomass was the second largest contribution to Area 1-3 total biomass but the lowest contribution to Area 6 total biomass (Table 14.1).

Trends already discussed in other reports may be noted in ant and large Coleoptera biomass in 1975 and 1976. In both areas ant biomass was generally predominant in winter and spring, while large Coleoptera biomass was predominant in summer and autumn. Generally the ants showed a trend of increasing biomass while the large Coleoptera showed a decreasing biomass over the 2 years when seasons were compared (Table 14.1).

Above-ground cage biomass in both areas showed an increasing trend from 1975 to 1976. Below-ground cage biomass results were evenly balanced between the 2 years in both areas but showed considerable fluctuation from season to season (Table 14.1).

Total biomass in each area showed a general increase between 1975 and 1976 (Table 14.1, Figure 14.1). Fluctuations in total biomass were more pronounced in Area 6 than in Area 1-3.

Table 14.2 and Figure 14.2 show the division of arthropod biomass into trophic categories of herbivores, carnivores and detritivores. Total seasonal biomass over the years showed carnivores to be of low biomass in both areas compared to herbivores and detritivores. In Area 1-3, herbivores and detritivores exhibited almost the same total biomass value (over the 2 years) but in Area 6 detritivores exceeded herbivores in total biomass by more than 10,000 g/ha (Table 14.2, Figure 14.2).

In Area 1-3, herbivore and carnivore biomass showed a general increase from 1975 to 1976 while detritivores were evenly balanced in biomass between the years. Herbivores also showed a biomass increase in Area 6 between 1975 and 1976, but carnivore biomass was evenly divided and detritivore biomass showed a slight overall decrease with sharp fluctuations

Table 14.1

Calculated Biomass of Ants, Large Coleoptera, and Total Above-and Below-Ground Arthropods Captured with Cage Sample in Areas 1-3 and 6 Between Spring 1975 and Winter 1976-77

Taxon	Grams Dried Arthropods per Hectare by Area and Season								
	Spring 75	Summer 75	Fall 75	Winter 75	Spring 76	Summer 76	Fall 76	Winter 76	2-4 yr. Total
Area 1-3 (Ungrazed)									
Ants	473.2	159.6	406.1	(1,103.5)[1]	1,800.9	1,515.5	1,660.5	1,408.2	8,527.4
Large Coleoptera	185.4	1,412.1	1,347.6	65.1	794.8	819.2	423.4	137.5	5,185.1
Cage Above Ground	330.3	421.4	331.0	427.6	4,791.1	3,716.0	1,087.7	2,408.0	13,512.9
Cage Below Ground	4,514.5	4,114.0	1,050.0	3,413.8	1,048.3	2,047.0	3,828.1	5,002.3	25,017.9
Totals	5,503.3	6,107.1	3,134.7	5,010.0	8,435.0	8,097.6	6,999.6	8,956.0	52,243.3
Area 6 (Heavily Grazed)									
Ants	335.1	84.5	571.1	(1,071.5)[1]	1,571.9	1,514.5	934.8	1,216.6	7,300.0
Large Coleoptera	624.0	2,066.7	279.6	32.5	411.7	680.0	326.9	6.3	4,427.7
Cage Above Ground	242.3	60.4	193.6	269.4	226.4	306.5	391.6	620.2	2,310.4
Cage Below Ground	5,031.0	176.0	4,913.8	7,931.9	3,136.4	3,232.3	7,550.9	3,892.8	35,865.0
Totals	6,232.4	2,387.6	5,958.1	9,305.3	5,346.3	5,733.2	9,204.2	5,735.9	49,903.0

[1] Values in parentheses for ant biomass are estimates only. No sample was taken in Winter 1975.

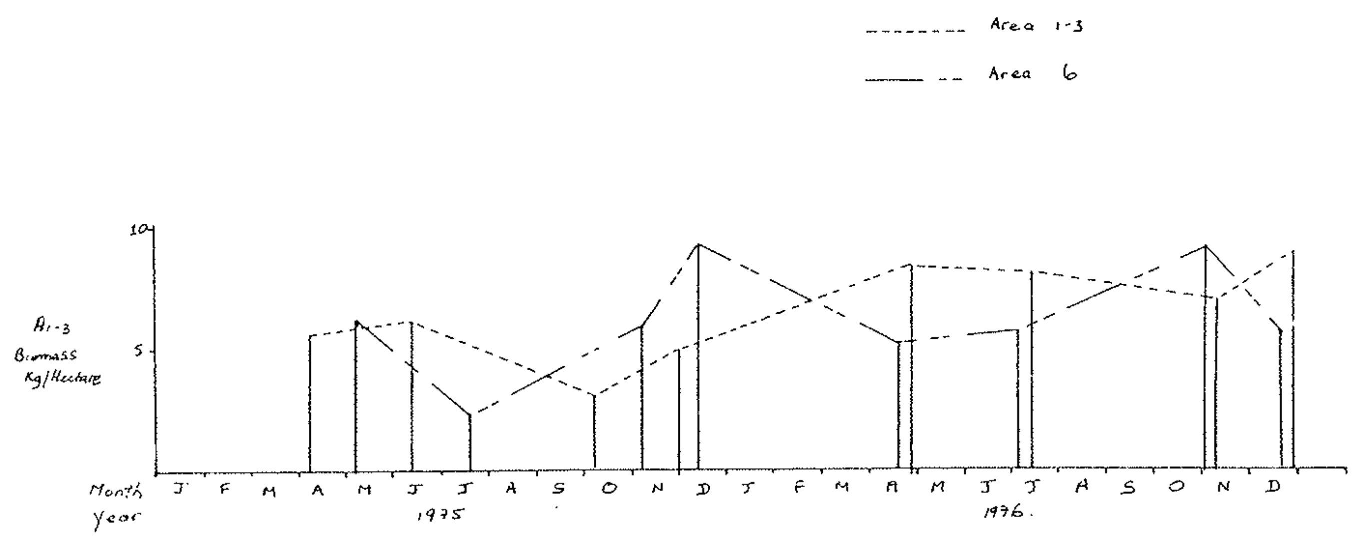

Figure 14.1. Total biomass (kg dry weight/ha) in Areas 1-3 and 6 estimated from cage, ant and large Coleoptera samples taken in 1975 and 1976.

Table 14.2

Calculated Arthropod Biomass in Each Trophic Level in Areas 1-3 and 6 Between Spring 1975 and Winter 1976-77

	Grams Dried Arthropods per Hectare by Area and Season								
Trophic Level	Spring 75	Summer 75	Fall 75	Winter 75	Spring 76	Summer 76	Fall 76	Winter 76	2-4 yr Total
Area 1-3 (Ungrazed)									
Herbivores	1,782.3	1,670.7	1,351.8	2,236.5	4,922.0	4,834.6	3,204.1	4,461.0	24,463.1
Detritivores	3,494.7	3,984.4	1,684.0	2,398.8	2,727.6	2,549.8	3,326.2	4,156.5	24,322.0
Carnivores	226.3	452.0	98.9	374.7	785.3	713.2	469.3	338.5	3,458.2
Totals	5,503.3	6,107.1	3,134.7	5,010.0	8,435.0	8,097.6	6,999.6	8,956.1	52,243.3
Area 6 (Heavily Grazed)									
Herbivores	1,427.8	754.6	1,529.8	3,178.2	2,201.1	3,543.8	2,579.3	2,668.2	17,882.7
Detritivores	3,813.3	1,433.7	4,112.0	5,709.6	2,759.1	1,812.3	6,072.4	2,287.8	27,990.2
Carnivores	991.4	209.3	316.2	417.5	386.2	377.2	552.5	779.9	4,030.1
Totals	6,232.4	2,387.6	5,958.1	9,305.3	5,346.3	5,733.2	9,204.2	5,735.9	49,903.0

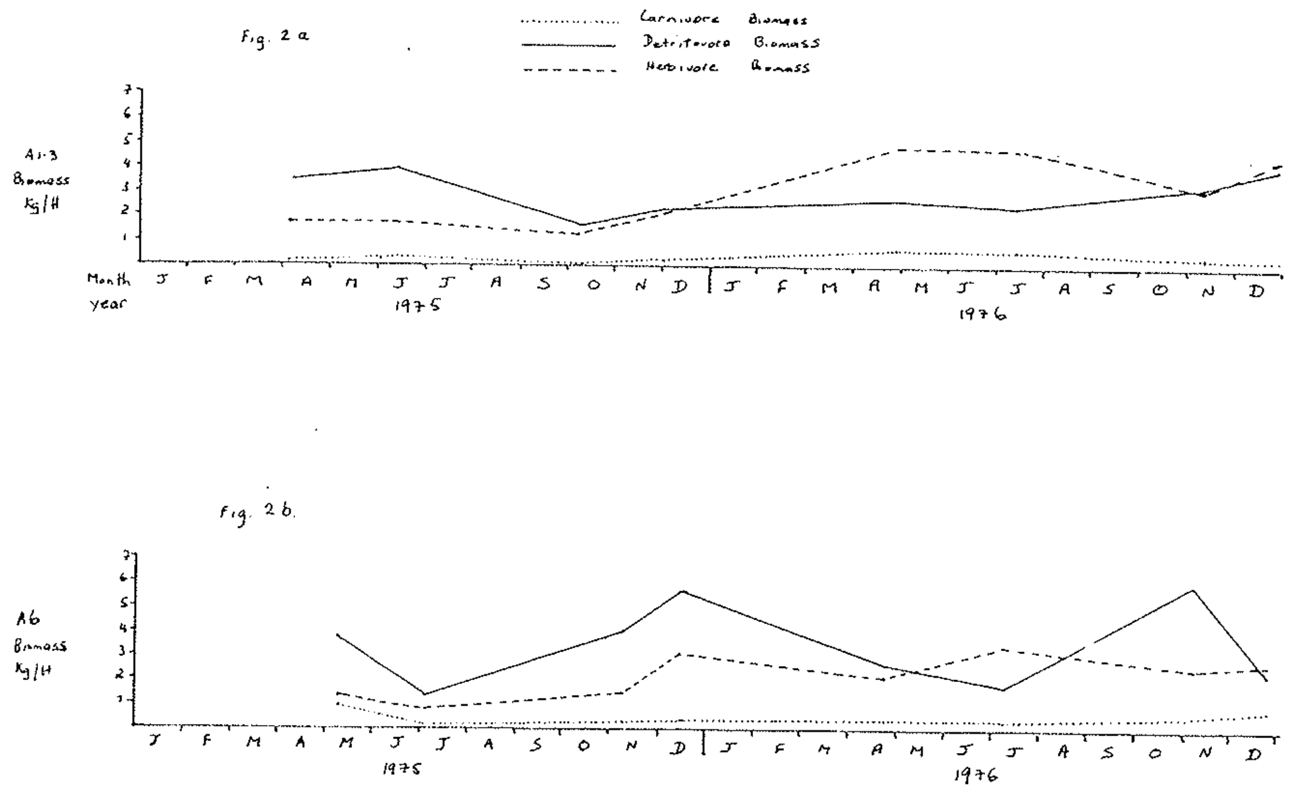

Figure 14.2. Total biomass (kg dry weight/ha) for herbivores,detritivores and carnivores in Areas 1-3 and 6 estimated from cage, ant and large Coleoptera samples taken in 1975 and 1976. Fig. 2a Area 1-3, Fig. 2b Area 6.

from season to season (Table 14.2, Figure 14.2).

Discussion

Though arthropod biomass estimates are still tentative and must be adjusted for sweep biomass results in many flying species, trends observed in total biomass and in the three trophic categories may be linked to land usage and climatic patterns.

The general increase in biomass shown by herbivores and carnivores in both areas over the 2-year period may be linked to increasing precipitation. For example, 186 mm precipitation were recorded in the 1974-75 rainfall season and 497 mm in the 1975-76 rainfall season. Resultant increased vegetation production (see vegetation sections by G. Novikoff, Report Nos. 4 and 5) has evidently influenced herbivore production, which in turn has stimulated carnivore production (Table 14.2, Figure 14.2).

The high herbivore production in Area 1-3 compared to Area 6, may be accounted for by land usage. Heavy grazing by livestock throughout the year in Area 6, reduces green vegetation available to arthropod herbivores and hence suppresses herbivore production. In non-grazed Area 1-3, arthropod herbivores are free from livestock competition and can exploit available food resources more effectively.

It may be noted that arthropod detritivores have a considerably higher biomass in Area 6 than in Area 1-3 (Figure 14.2). It is thought that this is due to the fact that much of the vegetation production in Area 6, is consumed by livestock which leave a residue of faecal pellets. Thus must of the annual production becomes available to arthropods in the form of fecal pellets in Area 6. Subterranean detritivores are thought to readily utilize this supply thus accounting for the high biomass of detritivores in Area 6 compared to Area 1-3.

CHAPTER 15

SECONDARY PRODUCTION OF SHEEP AND GOATS

by D. Coleman Crocker-Bedford
and Kara-Lynn Crocker-Bedford

Introduction

This chapter presents the gain in live weight of sheep and goats annually on a per unit area basis. It is separated into two sections: secondary production of young and secondary production of adults.

Secondary Production of Young

Methods.-- A viable young is defined as a lamb or kid present in mid-April, or slaughtered or sold before mid-April. Such an animal is nearly always beneficial, as opposed to young which die when too small to slaugher, or young which require much grain because they are born after mid-April.

The weight of viable young produced per unit area equals (the number of viable young per April female) X (the stocking rate of females in April) X (the body weight of the young when marketed or slaughtered). The numbers of viable young per female present in April were presented in Table 12.3 of Chapter 12 (Sheep and Goat Demography). The stocking rates of adult females in April were calculated with the same data used for Tables 5.1 and 5.2 of Chapter 5 on stocking rates. The average body weights of project lambs and kids when sold are exact. Neighboring lambs and kids were not weighed when marketed or slaughtered, but were visually compared in size to those of the project. Weights for 1974-75 were assumed to equal weights for 1975-76.

Results and discussion.-- Table 15.1 presents the production estimates for viable lambs and kids. These amounts exclude the few lambs and kids which died when they were too small to slaughter, as well as the very few lambs and kids which were born after mid-April.

The production of viable lambs and kids equals approximately 8 kg of live weight annually per ha of pasture. Some fodder and grain contribute to this secondary production. Of course, the annual production per unit area varies with the number of young per female, the stocking rates of ewes and does, and the selling or slaughtering weights of lambs and kids.

The number of young per female present in April was highest in 1976-77 and lowest in 1975-76. Details concerning the number of young per April female were discussed in Chapter 12.

Table 15.1

Secondary Production of Viable Lambs and Kids

Year and Animal Type	Project Animals No./Ha	Project Animals Kg/Ind.	Project Animals Kg/Ha	Neighbors' Animals No./Ha	Neighbors' Animals Kg/Ind.	Neighbors' Animals Kg/Ha
1974-75						
Lambs				0.217	23	5.0
Kids				0.201	15	3.0
Both				0.418		8.0
1975-76						
Lambs	0.219	25	5.5	0.159	23	3.7
Kids	0.156	16	2.5	0.179	15	2.7
Both	0.375		8.0	0.338		6.4
1976-77						
Lambs	0.305	17	5.2	0.283	20	5.7
Kids	0.297	13	3.9	0.247	13	3.2
Both	0.602		9.1	0.530		8.9

The sizes of neighboring flocks, and thus their stocking rates, increased by 20 percent between 1974-75 and 1976-77. We discuss this phenomenon in Chapter 5. On 12 April, 1976, the project had 0.50 adult females per ha, and the neighbors had 0.49 adult females per ha. Therefore, the project produced 11% more lambs and kids per unit area than did the neighbors, largely because of a greater birth rate, not because of a higher stocking rate. On 13 April, 1977, the project had 0.50 adult femles per ha, while the neighbors had 0.54 adult females per ha. Therefore, the project produced 14% more lambs and kids per unit area than did the neighbors because the greater birth rate of project animals more than offset the greater stocking rate of the neighbors.

The weights at which lambs and kids were marketed or slaughtered varied greatly. They were highest during 1975-76, when vegetational production was great. Weights are assumed to have been equally high in 1974-75, also a year of high forage production. In 1975-76, the project's young were heavier than the neighbors' because they were marketed later than those of the neighbors. The selling and slaughtering weights were lower in 1976-77, undoubtedly largely due to much lower primary production. The neighbors partially compensated for the low forage availability of 1976-77 by giving crushed barley grain to their young, especially to their lambs, but the project gave no special supplement to its young. Furthermore, in 1976-77 the grazing of all pastureland by neighboring lambs and kids gave them an advantage over project young, which intensively grazed most pastures only once.

It is important to note that supplement contributed to the weight of young produced per unit area. In 1975-76 prior to mid-June, after which time animals ceased to grow until fall, supplement amounted to 30 kg/ha for the project (the total amount of supplement divided by all 128 ha of project pastureland). We assume that a somewhat similar amount was given to neighboring flocks. In 1976-77 prior to mid-June, supplement amounted to 28 kg/ha for the project. We believe that neighboring flocks received somewhat more supplement. Thus the forage contributing to the production of sheep and goats consisted of the usable primary production per unit of pastureland plus approximately 30 kg of supplement per ha of pastureland.

Secondary Production of Adults

Methods.-- In the case of the neighbors, any individual animal could not be followed over time to determine the amount of its weight gain. Growth of individual project animals could be followed between November 1975 and May 1977, but the average growth during the period was probably more dependent upon the characteristics of the specific year than upon the aging of the animals. Therefore, to determine the average growth of adults, we decided to compare the differences in weights between the successive ages of adults.

Data from 29 September 1976 were employed. It was the only period, for which we have data, that a given dental class seemed to correspond to just one chronological age. Also, this date just followed the end of agricultural year 1975-76.

The difference between the average weight of a given age class and the average weight of the next successive age class was considered to be the average growth occurring between the two ages. The average annual growth of the average adult equalled the summation of the differences between the successive ages, each weighted by the proportion of adults occurring in the elder of each pair of ages.

Complete data were available only for females.

Results and discussion.-- Table 15.2 suggests that the average ewe gains 3.10 kg annually, and Table 15.3 that the average doe gains 2.16 kg annually. These gains may underestimate the true gains because the final growth of a culled animal is not included. Also, the yearlings have apparent weight losses when compared with the marketing and slaughtering weights of lambs at 23 kg and of kids at 15 kg (Table 15.1). These losses were partially due to real weight losses during July and August, after most marketing and slaughtering of young had already taken place. In addition, the neighbors tended to sell or slaughter their largest lambs and kids, which would have caused lamb and kid productions to have been overestimated.

However, these overestimates should have been exactly compensated by the resulting underestimates of adult growth.

On the other hand, two factors overestimate adult growth. More old animals than young animals are pregnant in late September, and so have more apparent weight. However, this amount should be small because most births are still over 2-months away. Secondly, it may be that the animals which are small for their age are the ones which are culled. If so, such culling would give the illusion of growth between the averages of the successive ages.

Although complete data were available only for females, sedasse rams were 27% heavier than sedasse ewes, and sedasse bucks were 77% heavier than sedasse does. We therefore assume that rams gain weight 1.27 times faster than do ewes, or 3.9 kg annually, and that bucks gain weight 1.77 times faster than do does, or 3.8 kg annually.

We will now combine the annual weight gains per adult with the stocking rates for 29 September 1976 (Table 5.1 of Chapter 5 on stocking rates):

3.10 kg/ewe/yr X 0.326 ewes/ha = 1.01 kg/ha/yr
3.9 kg/ram/yr X 0.03 rams/ha = 0.12 kg/ha/yr
2.16 kg/doe/yr X 0.271 does/ha = 0.59 kg/ha/yr
3.8 kg/buck/yr X 0.06 bucks/ha = 0.23 kg/ha/yr

Table 15.2

Annual Growth of the Average Ewe as Discerned from Weight Differences Between Ages on 29 September 1976

Approximate Age (months)	9	21	33	45	57	69+
Local Term for Dental Class	barchoussa	houlya	rebaya	sedasse	jamaa	cherf
Number of Ewes Observed	48	37	20	31	24	2
Average Body Weight (kg)	22.5	33.6	37.8	39.3	38.8	36.8
Fraction of All Ewes	.296	.228	.123	.191	.148	.012
Apparent Growth Since Previous Age (kg)	-0.5	+11.1	+4.2	+1.5	-0.5	-2.0
Contribution to Growth of Average Ewe (kg)	-0.15	+2.53	+0.52	+0.29	- 0.07	-0.02
Annual Growth/Average Ewe		$\Sigma = 3.10$ kg				

Table 15.3

Annual Growth of the Average Doe as Discerned from Weight Differences Between Ages on 29 September 1976

Approximate Age (months)	9	21	33	45	57	69+
Local Term for Dental Class	berchnias	jedaa	rebaya	sedasse	jamaa	cherf
Number of Does Observed	36	24	26	17	21	8
Average Body Weight (kg)	12.1	20.6	23.4	25.1	28.3	30.3
Fraction of All Does	.273	.182	.197	.129	.159	.061
Apparent Growth Since Previous Age (kg)	-2.9	+8.5	+2.8	+1.7	+3.2	+2.0
Contribution to Growth of Average Doe (kg)	-0.79	+1.55	+0.55	+0.22	+0.51	+0.12
Annual Growth/Average Doe			$\Sigma = 2.16$ kg			

Thus the toal weight gain for all adults together was approximately 2.0 kg/ha annually. This amount would have been less in previous years, when stocking rates were lower.

Total Secondary Production of All Age Classes

In summary, the total annual secondary production by sheep and goats is approximately 10 kg/ha. Of this total, 80% is by lambs and kids, and 20% by adults. Sheep production makes up 61% of the total, 39% is by goats.

CHAPTER 16

SOIL MICROBIOLOGICAL AND BIOCHEMICAL INVESTIGATIONS, 1972-76

by John J. Skujins

Introduction

This report describes the results of microbiological and biochemical investigations as well as pertinent physio-chemical analyses performed on southern Tunisian soils collected over the period October 1972-November 1976.

Initially, studies began at the Dar ez Zaoui (Chaabania) site and investigations provided some baseline information. Although the main emphasis of the study remained at the Dar ez Zaoui site (particularly the 20 m grid treatment area established in December 1973), specific areas of interest necessitated changes in the experimental design as well as the establishment of study plots at the Henchir es Siane site. Comparison samples (i.e. cultivated olive orchard and oasis soils) were also collected periodically outside the Dar ez Zaoui site. This diversity in emphasis and study areas makes quantitative, statistical assessment of the data difficult. The data, therefore, is generally discussed qualitatively and pertinent quantitative observations are made where apllicable.

The report is divided into sections wherein each phase or emphasis (i.e. effect of soil amendment treatments, cultivation and/or grazing practices) of the study is discussed separately. In addition, an especially important aspect of the study (microbial anlaysis) is reported independently. For comparative purposes, pertinent analyses of a number of samples from the North American Deserts are included.

Materials and Methods

Analytical methods used in this study have been those developed for the examination of the U.S. deserts under the US/IBP Desert Biome project and have been described previously. The determination of microbial numbers, soil respiration, dehydrogenase activity, proteolytic activity, organic carbon, total nitrogen, nitrate, nitrite, soil ammonium fractions, and soil pH in the first Progress Report and elsewhere (Skujins 1972, 1973). Other references to methods include those for water potential measurement (Skujins and West, 1973), nitrification potential (Skujins and Fulgham, 1974), ATP determination in soil (Skujins, 1975a), N_2-fixation (Skujins, 1975b) and physiological groups of microoganisms (Skujins, 1976).

State of the System and Biochemical Processes at Individual Sites

Sampling sites.-- Soil samples (64) from survey pits and various locations at the Dar ez Zaoui site were collected and analyzed for several soil chemical, physical and biological parameters during September-December 1972. The analyses were performed at both the field laboratory at Gabes and the Soil Biochemistry Laboratory at Utah State University. Results obtained were used to obtain baseline information on soil parameters and conditions and to select pertinent areas of interest for future investigations.

Results and discussion: The texture of Dar ez Zaoui soils is fine sand or loamy sand. This is in contrast to most North American deserts where the soils usually contain more or less clay. Consequently there is a lesser cation exchange capacity, lesser number of sorbtive sites per soil weight and poorer water-holding relationships for biological activities. The consequences of these characteristics are reflected in the values of biological activities all of which are by factors lower than those of North American deserts.

Elevated deydrogenase activity (Table 16.1) is present in surface 1 cm layers, similar to results in other deserts. Generally only traces of dehydrogenase activity are found below this level.

Dehydrogenase activity of soil "pavement" increases with its apparent age (sequence 5-32, 5-41, 5-23, 5-24, 5-47). Activity in hummocks (nebkas) and tufts depend on plant species. There is limited activity in *Aristida pungens* tufts, but higher activity under the shrubs *Rhanterium* and *Retama*.

High dehydrogenase activity is also found in sandy annual growth areas (S-8, S-25, S-43). The activity is significantly higher in non-grazed (the National Forest area adjacent to Dar ez Zaoui prior to its heavy use in the mid-1970's) areas as compared to similar vegetative and surface areas in the grazed (research) site, indicating that dehydrogenase could possibly be used as a measuring stick for recovery of the over-grazed sites. The S-14 sample represents a clay-containing soil outside the Chaabanía site, and its activity agrees with those found in North American clay-type deserts.

Decrease of activity with depth in all profiles is evident. There are pronounced differences between the surface and subsurface soils (samples S-1 to S-48), surface samples always showing the highest activities.

Soil respiration: The rate of CO_2 release from soils appears dependent on the available water content as determined by water potential measurements, and in general decreases with decreasing water potential.

Respiratory activity if somewhat lower than that of North American deserts, especially in the surface soils (samples S-1 to S-13), where the surface and subsurface relationship is reflected (surface soils having higher activities).

Proteolytic activity: Results on proteolytic activity are shown in Table 16.2. Although a gradual decrease with depth in the profile is discernible in Survey Pits 17 and 29, the reverse is shown for Pit 8. The two higher measurements in Pit 8 were made below the petrocalcic layer.

Table 16.1

Dehydrogenase Activity of Dar ez Zaoui Soils

Sample No.	mg Formazan/g-Soil	Sample No.	mg Formazan/g-Soil
8-1	0.028	S-16	0.007
8-2	0	S-17	0.038
8-3	0	S-18	0.015
		S-19	0.020
17-1	0.003	S-20	0
17-2	0.002	S-21	0.025
17-3	Trace	S-22	Trace
17-4	Trace	S-23	0.056
		S-24	0
29-2	0.002	S-25	0.032
29-3	0	S-26	0
29-4	0	S-27	0.147
29-5	Trace	S-28	Trace
		S-29	0.127
38-1	0.003	S-30	Trace
38-2	0.002	S-31	0
38-3	0.002	S-32	0.013
		S-33	0.010
S-1	Trace	S-34	0
S-2	0.003	S-35	0
S-3	0.002	S-36	0
S-4	0.010	S-37	0.055
S-5	Trace	S-38	0.018
S-6	0.118	S-39	0.007
S-7	0.008	S-40	Trace
S-8	0.182	S-41	0.027
S-9	0.005	S-42	0
S-10	0.143	S-43	0.053
S-11	0.007	S-44	0
S-12	0.073	S-45	0.040
S-13	0.040	S-46	Trace
S-14	0.23	S-47	0.087
S-15	0	S-48	0

Table 16.2

Soil Proteolytic Activity and pH of Dar ez Zaoui Soils

Sample No.	Proteclyfic Activity % Hydrolysis	pH
8-1	2.0	8.28
8-2	4.5	8.82
8-4	9.8	8.65
8-5	9.2	8.80
6	7.0	8.88
17-1	9.9	8.78
17-2	6.8	9.14
17-3	8.8	9.16
17-4	2.8	9.05
29-1	4.4	8.82
29-2	2.0	9.00
29-3	1.0	9.12
29-4	0	9.20
29-5	1.0	9.18
38-1	7.0	9.12
38-2	3.8	9.05
38-3	6.2	9.10
S-1	12	8.62
S-2	15	8.48
S-3	14	8.63
S-4	14	8.49
S-5	13	8.65
S-6	8	8.67
S-7	4	8.68
S-8	11	8.63
S-9	4	8.72
S-10	11	8.57
S-11	9	8.72
S-12	14	8.72
S-13	15	8.85

These proteolytic-activitiy levels are rather low. In the surface soils it is about 1/3 that found in North American desert soils.

The pH values (Table 16.2) fall in the same range as North American desert soils, indicating the high carbonate content and occasional salinity of the Dar ez Zaoui soils. The surface soils vary on the average between pH 8.3 and 8.7. pH is seen to increase with depth up to 9.2 in the case of soil Survey Pit 29 samples.

Salinity: The relationship of percent water content and water potential values is shown in Table 16.3. At a relatively high water content (about 10%) the water potentials do not reach above -4 bars (average), indicating salt effects in these sandy desert soils. This effect could be verified by EC_e measurements.

Nitrogen activity: Nitrate, ammonium, total nitrogen and organic carbon content of pit profiles No. 17, 29 and 38 are shown in Table 16.4 Chemical analysis of these soils shows that they are extremely poor in organic carbon (0.1 to 0.4% organic C) and nitrogen (0.02 to 0.04%). With such low concentrations, it is only marginally possible to obtain meaningful C/N ratios. It is evident however that the C:N ratios are 10 or less, indicating that all available organic matter has been used for N immobilization.

Nitrification potential experiments (Table 16.5) indicate that added NH_4^+ is not sorbed by the Dar ez Zaoui soils, in contrast to North American desert soils. This is expected due to the lack of clay in these soils (most of the ammonium added was lost by volatilization). Of the 13 soil samples, only two were found to show nitrification upon first priming with 0.01 M $(NH_4)_2SO_4$ (S-6 and S-9). Sample S-6 showed the highest nitrification rate. In some cases, samples showed no nitrification even upon second addition of ammonium sulfate. No correlation of depth to nitrification was found. Of major importance, however, was the observation that in some samples (S-4, S-6, S-9 and S-12) a large accumulation of nitrite occurred with very little of the NO_2^- subsequently oxidized nitrate (NO_3^-). The results indicate that soils are poor in nitrifier populations. However, a tendency for the NO_2^- accumulation under the experimental conditions is similar to the more pronounced effect in North American desert soils.

Dar ez Zaoui Experimentally Perturbed and Cultivated Soils

Soil sites and treatments.-- Thirteen soil treatment plots, 20x20 m in size were established in December, 1973 in a staked grid area of the Dar ez Zaoui site and numbered 1-8 and 11-15. Plots 9 and 10 were retained untreated as controls. Plot 13 was 10x20 m in size.

The soil treatment plots were established to examine the possibilities for biological control of wind erosion of desertified, arid-area surfaces and to obtain information on organic matter decomposition, nitrogen losses and exchange, revegetation and other biological processes.

Table 16.3

Water Potential and Percent Moisture Levels in Dar ez Zaoui Soils in Winter

Sample No.	Water Potential (Bars)	Moisture (%)
17-2	-8.6	6.5
	-8.4	11.5
17-3	-9.1	6.7
	-6.6	11.7
17-4	-4.6	7.9
	-2.0	12.9
29-2	-5.9	6.6
	-3.0	11.6
29-3	-8.4	7.3
	-5.5	12.3
29-4	-9.0	6.8
	-6.7	11.8
38-1	-7.6	6.6
	-3.1	11.6
38-2	-5.8	6.9
	-2.6	10.0
38-3	-10.5	7.7
	-4.5	12.7
S-1	-3.4	10.5
S-2	-5.3	10.7
S-3	-6.0	10.6
S-4	-6.5	11.5
S-5	-7.5	10.4
S-6	-4.0	10.6
S-7	-4.5	11.3
S-8	-5.7	11.1
S-9	-5.9	10.7
S-10	-3.8	10.7
S-11	-3.8	11.3
S-12	-3.6	10.7
S-13	-2.5	11.4

Table 16.4

Chemical Analyses of Dar ez Zaoui Soils

Sample No.	ppm NO_3-N	Total % N	% Organic Carbon	NH_4^+ - N µg/g soil
6	1.5	.04	.4	
17-1				16.0
17-2	.13	.02	.1	7.0
17-3	.13	.02	.2	6.4
17-4	.25	.03	.3	5.5
29-1	3.0	.03	.2	9.8
29-2	.13	.02	.1	5.3
29-3	<.1	.03	.2	4.8
29-4	.25	.02	.2	4.5
29-5	.25	.03	.2	2.8
38-1	.13	.02	.1	9.5
38-2	.38	.03	.1	8.0
38-3	.25	.03	.1	7.3

Table 16.5

Nitrification Potential of Dar ez Zaoui Soils

Sample	µg Nitrogen/g of Soil			
	NH_4^+-N Added	NH_4^+-N After 24 da	NO_2^--N After 24 da	NO_3^--N After 24 da
S-1	2342	542	22	1
S-2	2349	602	2	8
S-3	2345	437	46	0
S-4	2369	22	1554	7
S-5	2342	899	0	0
S-6	2347	0	1504	82
S-7	2359	815	210	4
S-8	2359	289	822	0
S-9	2347	1	1797	23
S-10	2347	523	2	0
S-11	2364	698	0	0
S-12	2347	2	1909	27
S-13	2366	686	2	0

Soil in sand dune, rippled sand, and loose sand with vegetation areas was treated with oasis manure (fumier d'oasis), hardwood shavings and palm leaves. The treatments were performed variously between December 26, 1973 and January 7, 1974.

The oasis manure (applied to three plots) contained straw, fine sandy soil, and sheep,goat and camel feces at various stages of decomposition. The applied weights (140 kg per plot) were natural (wet) weights of the material. The hardwood shavings, similarly were applied as received at the rate of 130 kg per plot and applied without augmentation to three plots. Palm leaves were chopped to about 1 cm^2 and smaller size. They contained approximately 50% water, and were applied without augmentation to two plots at the rate of 130 kg per plot.

Fertilizer grade urea, containing 46% nigrogen by weight was applied to two plots at the rate of 13 kg/plot along with 130 kg of shavings, to half-plot 13 at the rate of 6.5 kg along with 65 kg of shavings and to two plots at the rate of 13 kg per plot along with 130 kg of urea.

The applied materials were mixed to the depth of 3 cm. Palm-leaf and wood-shaving application was based on a rate of 10t/ha/10cm; urea application was based on the rate of 10:1 C/N ratio of organic matter (dry weight), containing 50% C. Areas with extensive desert pavement were not treated, but retained as a control.

Plots 3,5,8,13 and 15 (all of which had previously been treated with urea) were treated with additional nitrogen fertilizer, ammonium nitrate, 33.3% N, on November 21, 1974 at the following rates:

Plot No.	Fertilizer added	N added
3	9.750kg	3.250kg
5	4.880kg	1.630kg
8	9.750kg	3.250kg
13	4.880kg	1.630kg
15	4.880kg	1.630kg

The fertilizer was dissolved in water, at approximately 10% solution, and applied by using watering cans to insure a more even distribution, some penetration, and most importantly, not to disturb the developing crust.

Surface 5 cm samples for comparison were collected at representative cultivated sites in the Gabes Oasis, Kettana Oasis, El Hamma de Gabes Oasis, and a cultivated olive orchard approximately 50 m due south of the Chaabania field station.

The two new sampling stations were established at Dar ez Zaoui in May 1975 and consisted of a cultivated barley plot and a control plot designated as DZ-1 and DZ-2 respectively. A selected national forest area, adjoining the Dar ez Zaoui site was cultivated and seeded (December 1975) with wheat for use as cultivation comparison soils.

Plot designations are as follows:

TM-1: Sand dunes, oasis manure
TM-2: Sand dunes, wood shavings
TM-3: Sand dunes, wood shavings + urea
TM-4: Sand dunes, palm leaves
TM-5: Sand dunes, palm leaves + urea
TM-6: Rippled sand, oasis manure
TM-7: Rippled sand, wood shavings
TM-8: Rippled sand, wood shavings + urea
TM-9: Control
TM-10:Control
TM-11:Loose sand w/plant cover, oasis manure
TM-12:Loose sand w/plant cover, wood shavings
TM-13:Loose sand w/plant cover, wood shavings + urea
TM-14:Loose sand w/plant cover, palm leaves
TM-15:Loose sand w/plant cover, palm leaves + urea

5 control, 4/5 control: Designates representative sample of untreated soil collected about 1 to 2 m outside the 15 plots

DZ-1: Cultivated barley, 0-20 cm
DZ-2: Cultivated barley control, 0-20cm

F-1-1: National forest area (0-20cm) disced, stubble intact
F-1-2: National forest area (20-40cm) disced, stubble intact
F-2-1: National forest area (0-20cm) traditional plowing, stubble grazed
F-2-2: National forest area (20-40cm) traditional plowing, stubble grazed
F-3-1: National forest area (0-20cm) disced, stubble grazed
F-3-2: National forest area (20-40cm) disced, stubble grazed
F-4-1: National forest area (0-20cm) traditional plowing, stubble intact
F-4-2: National forest area (20-40cm) traditional plowing stubble intact
FC-5: National forest area (0-20cm) non-cultivated control between F-1 and F-4
FC-6: National forest area (0-20cm) non-cultivated control between F-1 and F-2
FC-7: National forest area (0-20cm) non-cultivated control between F-2 and F-3
FC-8: National forest area (0-20cm) non-cultivated control between F-3 and F-4

No significant differences in pH between treatments or controls in the 20 m grid were observed over the sampling period, December 1973-November 1976. pH values averaged between 8.3 and 8.7 for treatment samples with all control samples averaging 8.5. Oasis soils collected in November 1974 reflected a somewhat lower pH, averaging 8.0. Cultivation-comparison soils collected in the national forest area (F and FC samples) at Dar ez Zaoui were similar to the treatment (TM) samples ranging from 8.2-8.8 and with no significant differences between cultivated and control soils noted. The pH values of these soils are expectedly alkaline and are similar to those noted for U.S. desert soils. $CaCO_3$ is presumably the factor most contributing to the high pH in these soils.

Average percent moisture of these soils at the time of collection may be compared with the respective water potential values as in the previous section. It is notable that the control soils (May 1975) exhibited a -47 bar lower average water potential than treatment soils at the same average moisture content.

Treatment Plots TM-12 and TM-13 exhibited the greatest mean values for organic carbon content (0.16 and 0.17%) of all grid treatment plots. Plot 11/13 control, however, averaged 0.19% organic carbon over the collection period and was the highest value determined for all grid samples. Similarly, the 7/8 control plot was higher in organic carbon than either Treatment Plot 7 (no N added) or 8 (N source added) by 0.1%. The control samples for Treatment Plots TM-4 and TM-5 averaged 0.12% organic carbon which was 0.1% lower than Plot 4 (no N source added) and 0.1% higher than Plot 5 (N source added).

The data would thus suggest that added organic matter (i.e., palm leaves and oasis manure) does not tend to accumulate but is rapidly utilized by the microbial population as a nutrient and energy source, especially with an added nitrogen. Increased biochemical activities in the same treatment soils over the control plots (especially microbial respiration rates) support this contention.

Cultivation-comparison samples (national forest area Samples F and FC) were slightly higher than grid treatment and control samples but still averaged less than 0.2% organic carbon with non-cutlivated controls somewhat lower in organic carbon than cultivated soils. Oasis-comparison soils (November 1974) contained markedly more organic carbon than grid or cultivation-comparison soils, as expected, and averaged 0.9% organic carbon.

Mean values for total nitrogen ranged from 0.02% to 0.06% in the grid treatment and control samples over the collection period. Control samples averaged approximately 0.01% lower total nitrogen than non-urea treatment samples and approximately 0.02% lower than urea-treated samples. Cultivation-comparison soils reflect analogous values for percent total nitrogen with no difference between cultivated and control soils discernible. Oasis-comparison soils were about three times as high in total nitrogen as either grid or cultivation-comparison soils.

Due to the very low values for organic carbon and total nitrogen noted above, traditional interpretation of the C/N ratio would be misleading. The few approximate C/N ratio values indicate, however, that the C/N ratios in these soils are 10 or less, as would be expected in desertic situations.

Nitrogen in the form of nitrate, expressed as $\mu g\ NO_3^- - N$/g-soil reached a peak in all urea-treated plots following urea addition in July 1974 samples (Table 16.6). Nitrate content declined thereafter to levels equivalent to those determined in the control soils. Plots TM-8 and TM-13, however, remained significantly higher in nitrate nitrogen than control soils up through the May 1975 collection period. Although somewhat increased levels of nitrates were determined initially, it appeared that oasis-manure-treated soils had no significant effect on soil nitrate levels overall.

Table 16.6

Nitrate Nitrogen in Treated, Control and Sampled Soils in Southern Tunisia

Sample	Dec. 1973-Jan. 1974	July 1974	Nov. 1974	May 1975	Nov. 1976
M-1	2.5	2.4	1.1	0.2	
M-2	1.6	2.4	0.9	0.2	
M-3	8.2	25.8	13.9	2.0	
M-4	0.7	1.1	0.7	0.3	
M-5	2.2	24.8	1.2	1.2	
M-6	0.8	1.0	0.5	0.4	
M-7	1.1	0.8	0.1	0.5	
M-8	1.4	30.8	5.4	8.6	
M-9	0.8	0.7			
M-10	1.2	0.7			
M-11	1.2	1.7	0.7	0.4	
M-12	1.1	0.8	2.0	0.4	
M-13	1.6	33.5	3.2	12.8	
M-14	1.6	0.8	0.6	0.5	
M-15	0.7	14.0	1.9	0.9	
5 Control		1.2			
10 Control		1.2			
15 Control		1.0			
1/5 Control			0.4	0.7	0.2
7/8 Control			1.4	0.6	0.1
1/3 Control			0.4	0.5	0.1
Olive Orchard		1.0			
Gabes Oasis			1.1		
ElHamma Oasis			5.3		
Kettana Oasis			0.4		
DZ-1				0.5	
DZ-2				0.1	
F-1-1					4.2
F-2-1					0.9
F-3-1					3.9
F-4-1					1.0
FC-5 Control					0.4
FC-1 Control					0.8

Cultivation-comparison soils collected in November 1976 showed slightly lower NO_3-N levels than grid control soils. Oasis soils collected in November 1974 ranged from 0.4 to 5.3 μg NO_3-N per gram of soil and averaged higher than grid control samples. Generally, the research-site soils had low nitrate content and any added nitrate did not persist over a period of one season under our experimental conditions.

Ammonium also is low and possibly limiting as a nitrogen nutrient in these soils. Total NH_4^+-N mean values did not exceed 35.5 μg/g-soil in any treatment or control plot and was as low as 6.0 μg NH_4^+ -N/g in the TM-1 (dune) sample. (The individual values during the period fluctuated between 1.7 and 115.)

Fixed ammonium constituted the bulk of NH_4^+-N present in these soils but was as well very low as compared to Tunisian oasis soils, and soils from U.S. deserts, due to the absence of clay fractions in these soils. The mean values (Table 16.7) of fixed NH_4^+-N ranged from 3.15 to 29.78 μg/g-soil with the highest values found in the loose sand area samples due in part to the increased organic matter present. All treated samples contained greater mean NH_4^+-N than their respective controls. Extremely low exchangeable ammonium, 1.28-10.76 μg NH_4^+-N/g-soil for treatment and control mean values (Table 16.7) were found reflecting the low cation exchange capacity of these soils.

Values generally increased with organic matter content, as in the absence of clay. Organic matter is the major source of exchange sites in the soil. In addition to this poor facility for nutrient retention, volatilization of ammonia is probably very high. The high alkaline pH of these soils facilitates the formation of NH_3 upon ammonification and this is lost to the atmosphere. (Due to the compexities involved in this project, the denitrification potential was not investigated.) Losses due to leaching are non-existent due to the low moisture conditions generally prevalent.

Increased biological activity in response to treatments in the 20 m grid at Dar ez Zaoui was most pronounced in the loose sand w/plant cover plots (TM-11 to TM-15) with plot TM-14 (palm leaves added) representing the highest activities determined overall. Respiration and proteolytic activity were especially high in this plot when comparied to control soils (Table 16.8). Although an initial response of biological activities to urea additions was evident, averaged values for Treatment Plots 3,5,8,13 and 15, as compared to averaged control values, showed that the long-term effects were negligible.

Non-treated control plots TM-9 and TM-10 exhibited average respiration rates equivalent to treatment plots; however, other plot controls (i.e., 4/5, 7/8 and 11/13 control) averaged about 35% less CO_2 evolved per gram of soil than the corresponding treatment plots. Comparatively, controls averaged about 30% less proteolytic activity and 31% less dehydrogenase activity than their respective treamtent plots (Table 16.8).

Table 16.7

Mean Values (All Sample Dates) for Physical and Chemical Soil Factors in Treatment and Control Samples at Dar ez Zaoui

Sample	pH	Water %	Water Potental -Bars	Organic Carbon %	Total Nitrogen %	Fixed Ammonjom µg NH_4^+-N/g	Exchangeable Ammonum µg NH_4^+-N/g	Nitrate Nitrogen µg NO_3^--N/g
TM-1	8.4	2.6	234	0.09	0.05	3.15	2.82	1.25
TM-2	8.5	2.7	277	0.12	0.05	4.60	2.50	1.03
TM-3	8.4	2.4	269	0.11	0.05	8.08	3.06	9.99
TM-4	8.5	2.8	250	0.13	0.03	7.95	2.72	0.58
TM-5	8.4	2.9	324	0.11	0.03	9.50	3.74	5.98
TM-6	8.4	2.4	288	0.11	0.04	4.95	3.90	0.55
TM-7	8.5	2.3	298	0.11	0.03	15.88	1.28	0.50
TM-8	8.3	2.3	281	0.11	0.06	6.87	8.70	11.55
TM-9	8.7	2.4	281	0.10	0.03	7.70	4.55	0.75
TM-10	8.6	2.4	290	0.10	0.04	5.20	3.85	0.95
TM-11	8.3	4.3	291	0.12	0.03	12.53	3.02	1.06
TM-12	8.5	3.6	291	0.16	0.04	14.98	1.74	0.86
TM-13	8.5	3.0	299	0.17	0.03	23.65	10.76	10.43
TM-14	8.3	2.8	246	0.12	0.02	29.78	5.72	0.71
TM-15	8.5	2.9	265	0.10	0.04	5.70	5.68	4.38
4/5 Control	8.5	3.0	359	0.12	0.03	5.58	4.30	0.50
7/8 Control	8.5	2.6	356	0.13	0.02	4.00	4.60	0.70
11/13 Control	8.5	4.8	337	0.19	0.02	12.50	2.70	0.93

Table 16.8

Mean Values (All Sample Dates) for Soil Biochemical in Treatment and Control Samples at Dar ez Zaoui

Sample	Respiration µmoles CO_2/g-soil/min	Proteolysis % Hydrolysis	Dehydrogenase mg FORMAZAN/g-soil	ATP Concentration µg ATP/g-soil
TM-1	7.16	6.32	0.007	0.029
TM-2	8.82	8.56	0.005	0.048
TM-3	10.42	8.54	0.007	0.031
TM-4	7.10	6.14	0.011	0.053
TM-5	8.26	7.82	0.012	0.058
TM-6	9.82	5.66	0.010	0.032
TM-7	11.26	6.24	0.015	0
TM-8	7.08	4.88	0.010	
TM-9	12.25	4.25	0.008	
TM-10	13.20	3.25	0.005	
TM-11	10.14	5.92	0.022	0.032
TM-12	12.88	8.28	0.021	0.013
TM-13	11.74	9.08	0.016	0.031
TM-14	18.06	11.64	0.018	0.118
TM-15	12.73	9.50	0.014	
4/5 Control	5.50	8.27	0.006	0.022
7/8 Control	5.27	6.50	0.012	0.008
11/13 Control	9.90	4.93	0.015	0.022

Although, as mentioned above, greatest activities were noted in treated loose sand w/plant cover soils, overall quantitative differences between treatments were small. The largest overall difference between activities of the various treatments was found in plots TM-11 to TM-15, averaging approximately 20% higher activities than the mean value for all treatments (Table 16.8). Area-comparison (oasis) soils averaged 71%, 70% and 82% higher activities for respiration, proteolysis and dehydrogenase activity respectively than grid-treatment soils. No significant differences between cultivated and non-cultivated control soils in the national forest samples for respiration were evident. Respiration rates were essentially equivalent to those noted for grid-treatment soils averaging 11.8 moles CO_2/g-soil/min. Dehydrogenase activity in national forest soils was higher than those of the research site. Control samples exhibited less dehydrogenase activity and more proteolytic activity than cultivated-comparison samples.

ATP concentration in μg ATP/g-soil ranged from 0 to 0.118 for December 1975 analyzed samples in the 20 m grid soils at Dar ez Zaoui. The highest value (0.118 μg ATP/g-soil) was found in plot TM-14 which, as noted above, reflected the highest activities determined as well. Treatment plots averaged approximately 50% higher ATP than control soils in the case of plots TM-4 and TM-5 with plot 11/13 control about 18% higher than its respective treatment plots (Table 16.8). Cultivation-comparison soils averaged about 12% less ATP per gram of soil than their respective controls and about 27% less than the mean value for grid-treatment soils.

Results of nitrification potential studies on Dar ez Zaoui soils indicate that treatment soils have no greater capacity for nitrifying added ammonium than control soils from the 20 m grid (Table 16.7). The highest value for nitrate formed during the incubation period was 40.8 μg NO_3^--N/g-soil which represented only 1.7% of the added NH_4^+-N. Cultivation-comparison soils (F-1-1, F-2-1 and F-3-1), however, showed higher nitrification rates than the corresponding FC-5 control with the F-1-1 sample nitrifying 8.9% of the added NH_4^+-N to NO_3^--N after 20 days incubation.

An appreciable accumulation of nitrite occurred in several samples. No correlations between samples in which this accumulation occurred were evident.

Given the extremely low nitrification potentials noted here, it is apparent that some factor(s) is inhibiting the oxidation step of the nitrite (NO_2^-)ion to nitrate (NO_3^-) and/or nitrate once formed is rapidly denitrified, although this has not been studied in these soils, and appears unlikely due to the low organic matter availability. Oxidation of ammonium to nitrite and nitrate may be limited also by the possible inherent absence of a substantial Nitrosomonas and Nitrobacter populations. A lag time of more than the 21 days of the nitrification experiment may be necessary to build up such populations.

The November 1974 treatment samples were examined for aggregation by using a physical dispersion test. No significant differences were found. This test, however, may not give significant results in very sandy soils, as in the Dar ez Zaoui site.

The development of soil crusts in desert situations is a long process and further examination of the soils might show their responses to treatments in soil stabilization processes.

Three types of desert pavement may exist in the study area: (1) mechanically created pavement. Cultivation of desert creates a compacted layer directly below the cultivated layer (cf. Novikoff, Chapter 14 of Progress Report No. 5). In a dry season the loosened surface layer is removed by wind action and the hard, compacted layer is exposed. (2) Physio-chemically created pavement may be established due to wind sorting of heavier particles which remain in place and also to cementing action by soil chemicals, especially by carbonates, if located close to the petrocalcic layer. (3) Biologically created pavement may be due to the microbial activity evident in places where short-term puddling occurs during a rainy period. This is a rather fragile pavement, needs organic matter (litter) for establishing itself and lower animals (insects) may play a major role here in transportation and mixing of litter.

Some algae were observed on the pavement surface, but infrequently, and their role has not been examined in detail yet.

Effects of Grazing at Dar ez Zaoui

Site description.-- Samples were collected in November 1976 perpendicularly across the northwest fence on a 42 m transect line between grazed and ungrazed areas at Dar ez Zaoui. The soils were examined for gross differences between soil parameters as a result of the grazing practices.

Sample designations are as follows:

Grazed area:	TS-1a:	(0-5 cm)	*Schismis* sp. vegetation
	TS-1b:	(20-40 cm)	" " "
	TS-2a:	(0-5 cm)	*Helianthemum* sp. vegetation
	TS-2b:	(20-40 cm)	*Schismis* sp. vegetation
	TS-4a:	(0-5 cm)	" " "
	TS-4b:	(20-40 cm)	" " "
Ungrazed research-site enclosure:	TS-11a:	(0-5 cm)	*Zollikoferia* sp., *Schismus* sp.
	TS-11b:	(20-40 cm)	
	TS-13a:	(0-5 cm)	*Rantherium suaveolens*, *Cutandia divaricata*
	TS-13b:	(20-40 cm)	
	TS-14a:	(0-5 cm)	*Schismus* sp.
	TS-14b:	(20-40 cm)	

Each consecutively numbered site was 3 m apart from the next one.

Chemical and physical properties.-- No significnat differences in salinity were observed between the grazed and ungrazed area soils, and salinity was low overall with electrical conductivities ranging from 0.2-0.4 mmhos 1 cm throughout. These values are comparable to other desert ecosystems.

Cation exchange capacity was extremely low averaging 3.5 and 3.3 meq/100 g in the grazed and ungrazed area soils, respectively. Absence of clay and low organic matter content in these soils are responsible for the low CEC values noted.

Phosphorous in grazed and ungrazed samples averaged again a low <0.01% in both cases. Although a mean difference of only 0.1% moisture was evident, water potential averaged 11% more negative in the grazed than ungrazed sample. Surface soil pH varied between pH 8.4 and 8.6 in both situations, reaching pH 8.7 in the 20 to 40 cm layer.

Organic carbon values although averaging 0.04% higher in the grazed area samples are insignificant given the 0.1% accuracy of the analysis involved and both area mean values can therefore be considered equivalent. Total nitrogen values were very low in both areas averaging 0.017 and 0.013% respectively in the grazed and ungrazed soils.

Fixed ammonium in transect surface samples was considerably greater in the ungrazed (11.43 μg NH_4^+-N/g-soil) than the grazed (0.23 μg NH_4^+-N/g-soil) area. Conversely exchangeable ammonium was twice as high in the grazed area as in the ungrazed area samples. Although the reasons for these results are not clear, it is possible that in part they reflect the quality and the cation exhange capacity of the organic matter present in these soils.

Nitrogen in the form of nitrates averaged 0.13 μg/g-soil higher in the grazed area than ungrazed area.

Biochemical activities.-- Biochemical activities determined for the ungrazed area samples were higher than those of the grazed area, particularly in the 0-5 cm surface samples (Fig. 16.1 and 16.2). Most apparent was a difference of more than 100% between grazed and ungrazed soils in mean dehydrogenase activity.

Ungrazed area samples contained between 0.006 and 0.009 μg ATP/g-soil with a mean surface soil average of 0.009 μg ATP/g-soil. Grazed area surface samples averaged about 24% less than grazed with values ranging from 0.004-0.009 μg ATP/g-soil.

Although no significant quantitative differences in nitrate production between grazed and ungrazed surface samples were observed (essentially nil in both cases), nitrate accumulation after 20 days incubation was about 30% higher in the grazed samples.

The mean values for parameters showing apparent differences between the grazed and ungrazed areas are shown in Table 16.9. (Note: The values do not yield to rigorous statistical treatment, due to limited sample number,

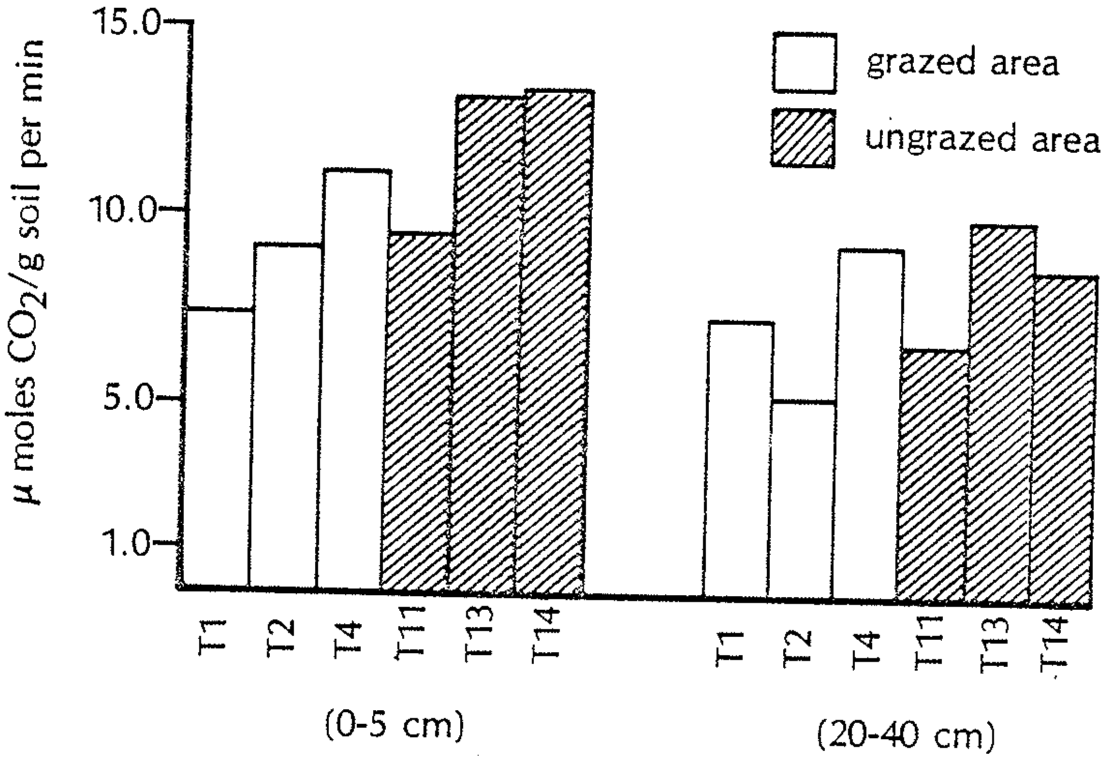

Figure 16.1. Comparison of respiration rates at two depths in the grazed and ungrazed area of the transect (TS) line, Dar ez Zaoui.

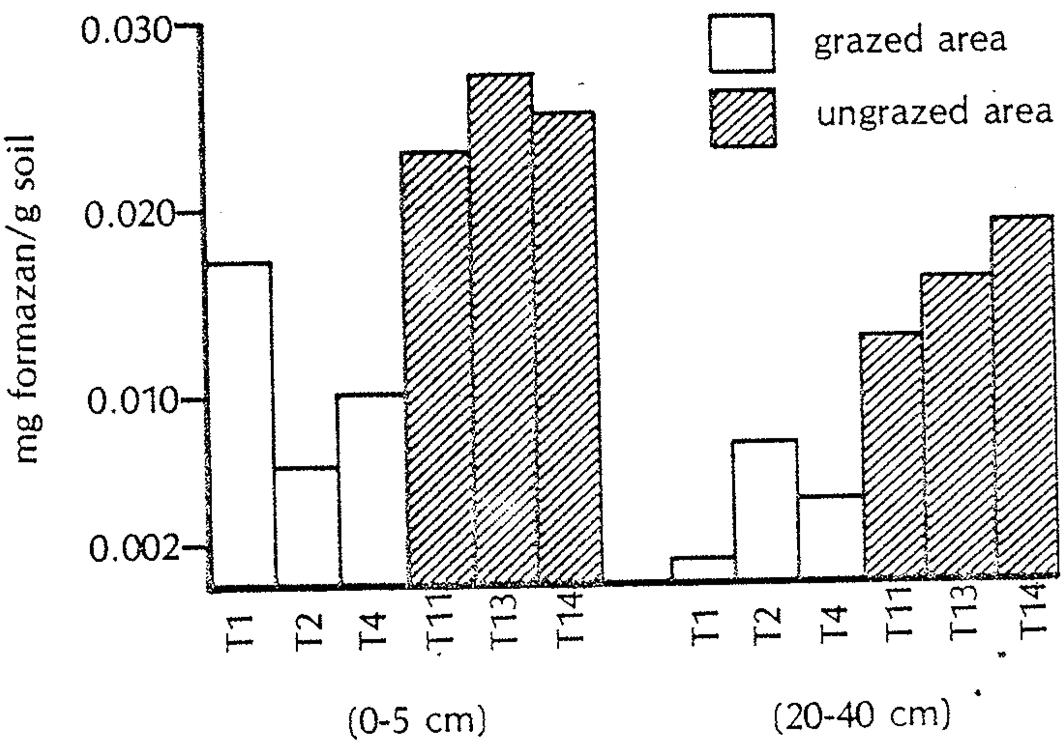

Figure 16.2 Comparison of dehydrogenase activity values at two soil depths in the grazed and ungrazed area of the transect (TS) line, Dar ez Zaoui.

Table 16.9

Mean Soil Physical and Chemical Parameters in Grazed and Ungrazed Areas of the Dar ez Zaoui Site

Parameter (0-5 cm Depth)	Grazed Area	Ungrazed Area
% Moisture	0.7	0.6
Water Potential (-Bars)	746	661
Respiration (μ moles CO_2/g/min)	9.2	11.9
Dehydrogenase (mg Formazan/g)	0.011	0.025
ATP Concentration (μg ATP/g)	0.007	0.009
% Organic Carbon (trend only, statistically not significant)	0.11	0.07
% Total Nitrogen	0.017	0.013
Fixed Ammonium (μg NH_4^+-N/g)	0.23	11.43
Exchangeable Ammonium (μg NH_4^+-N/g)	11.90	5.83
Nitrate Nitrogen (μg NO_3^--N/g)	0.73	0.60

and often low concentration and activity values, marginal for detection, as throughout this report.) The following trends may be noted:

Respiration, dehydrogenase and ATP values are higher in the ungrazed soils than the grazed indicating higher microbial activity, probably due to higher litter availability. The trend for lower C and N content in the ungrazed area might be due to higher microbial activity ("priming effect" by litter influx). The differences in the fixed and exhangeable ammonium distribution might also reflect the quality of available organic matter, among other factors.

The differences in the percent water content and water potential relationships are noteworthy. With decreasing water content in the ungrazed area, water potential was lower. In a soil with the same properties, the reverse should be true. In arid desert soils such behavior would reflect changes in salinity, among other factors, but no difference in conductivity (EC_e) was noted between the two situations.

<u>Henchir es Siane Site</u>

<u>Site selection and treatments</u>.-- Henchir es Siane site was added for the May 1975 collection. The site contains four parcels (I,II,III,IV) from which samples were collected and are designated as follows:

H-I-1: (0-5 cm), Parcels I and IV, winter and fall sheep and goat grazing
H-I-2: (5-20 cm), " " " " " " " " " " "
H-II-1: (0-5 cm), Parcel II, spring goat grazing
H-II-2: (5-20cm), " " " " "
H-III-1:(0-5 cm), Parcel III, spring sheep grazing
H-III-2:(5-20cm), " " " " "

Portions of Parcel I were cultivated December 28, 1975, and samples were collected. The following designations are used in this report:

HS-1-1: (0-20 cm); disced
HS-1-2: (20-40 cm), "
HS-2-1: (0-20 cm), plowed, conventional
HS-2-2: (20-40 cm), " "
HS-3-1: (0-20 cm), disced
HS-3-2: (20-40 cm), "
HS-4-1: (0-20 cm), plowed, conventional
HS-4-2: (20-40 cm), " "
HS-1/2 control: (0-20 cm), uncultivated control between plots HS-1 and HS-2
HS-2/3 control: (0-20 cm), uncultivated control between plots HS-2 and HS-3
HS-3/4 control: (0-20 cm), uncultivated control between plots HS-3 and HS-4

Additional samples were collected in November 1976.

Results and discussion.-- Due to the lack of extended data available on the systems involved, a rigorous comparative analysis of results with respect to the cultivation and grazing operations at Henchir es Siane sites is not possible at this time. The data do, however, provide useful baseline information and will be treated qualitatively. Notable differences, where apparent, between treatments will be pointed out but cannot be considered statistically significant.

The pH values at all sites are typical for desert ecosystems ranging from 8.3-8.8 over the sampling periods with an all-site mean of 8.6.

A very low water-availability relationship between percent moisture and water potential is evident in Henchir es Siane soils. Increasing moisture raises water potential to values in the available water range and "bursts" of microbial activity are evident. Salinity, although very low (EC_e averages about 0.2 mmhos/cm), and the cation exchange capacity (mean value 4.8 meg/100 g) in these soils contribute in part to the very low water potentials noted.

The total absence of clay combined with very low organic carbon values (less than 0.3% in all samples) are responsible for the very low cation exchange capacity noted above. CEC ranged between 4.5 and 5.3 meq/100 g. By comparison CEC values in U.S. desert soils average between 10 and 40 meq/100 g.

Available phosphorus is also low in these soils averaging 1.5 μg/g or less than 0.01% as compared to an average between 15-25 μg/g in typical U.S. desert surface soils. Extractable potassium ranged between 159 and 185 μg/g with again no distinct differences in treatments or samples evident.

Percent $CaCO_3$ equivalent in May 1975 samples ranged between 1.8 and 5.4, with the Parcel I, HI-1 sample 1.3% less than its control. In addition, HS-1-1 and HS-2-1 (disced and conventionally plowed surface samples respectively) contained 3.4 and 3.3% $CaCO_3$ which was about 2.1% less than the control (HS-1/2 C) sample.

Organic carbon content determined for Henchir es Siane sites reflects a low steady-state condition in regard to organic matter inputs and decomposition. Values range between 0.07% and 0.26% organic carbon with variations at any one site seldom exceeding 0.1%. Accumulation of organic matter thus appears non-existent in these soils. All treatment soils exhibited lower organic carbon values than control soils with the largest treatment-control difference noted between site HI-1 and HI-2 (0-20 and 20-40 cm depth samples in the combined sheep and goat, winter-and-fall grazed area) or 0.06%.

Total nigrogen values as well were extremely low and did not exceed 0.03% at any site. A fairly consistent average of 0.02% total nitrogen was maintained throughout the collection period.

Nitrate-nitrogen ($NO_3^=$-N) values ranged between <0.1 and 1.90 μg/g for all sites over the collection periods. These very low values suggest several possibilities and in reference to supporting data (ammonium analyses, nitrification studies, pH) it appears that ammonium is limiting as a substrate to the nitrifying population and that nitrate is rapidly utilized by plants.

Ammonium values as well are comparatively low but somewhat higher than values noted for Dar ez Zaoui sites overall. Fixed ammonium is generally lower than exchangeable due again to the absence of clay in these soils. Control soils from Parcel I contained more NH_4^+ in both fixed and exchangeable forms than the less grazed Parcel II and III samples.

The nitrogen and carbon relationships in these soils appear to be characteristic of arid desert soils in general.

Biochemical activities overall were very low with dehydrogenase activity ranging between 0 and 0.117 mg formazan/g-soil over the collection period. A mean value for all sites was typical of desert soils at 0.017 mg formazan/g-soil Respiration as well was very low and overall was between 0 and 24.1 μ moles CO_2/g-soil/min. Respiration for all sites over the collection period averaged 8.6 μ moles CO_2/g-soil/min. To evaluate the quantitative differences between treatment sites, values for biological activities of a number of consecutive seasons are needed.

ATP concentration decreased an average of 0.015 μg/g-soil from the relatively wet December 1975 to the very dry November 1976 collection periods in Henchir es Siane cultivated and control samples. December 1975 samples ranged between 0.008 and 0.034 μg ATP/g with a mean value of 0.020 μg ATP/g and November 1976 values were between 0.003 and 0.006 μg ATP/g-soil. No significant differences between control and cultivated plot samples were evident.

Nitrification potential in the Henchir es Siane soils is extremely inhibited. In none of the samples analyzed was added ammonium (NH_4SO_4) oxidized completely to nitrate (NO_3^-) to any appreciable degree during the 21 day incubation period. In several cases however (particularly the control soils) large accumulation of nitrite were observed. A characteristic lag period of about 12 days was evident before nitrification rates (i.e. first step involving oxidation of ammonia to nitrite) became substantial.

Microbial Characteristics

Dar ez Zaoui soils.-- Methods used and site designations are the same as described in previous sections. Baseline work was done on soils at this site in 1972. Further work involved investigations of microbiology of soil crusts and effects of plant canopies (i.e. rhizosphere). Also pertinent to the discussion here are the results on control plots of the Treatment Plot soils (TM series) and a report by R.M. Johnson (1973). Microbial numbers are shown in Table 16.10.

Table 16.10

Numbers of Microorganisms Calculated for Dar ez Zaoui Soil Samples in 1972

Sample No.	Bateria and Streptomycetes (#/g soil)	Fungi (#/g soil)
8-1	260,000	6,400
8-2	170,000	1,800
8-3		
8-4		400
8-5		300
8-6		100
17-1	330,000	200
17-2		800
17-3		300
29-1	300,000	200
29-2	380,000	500
29-3	200,000	400
29-4	80,000	300
29-6	100,000	
38-1	160,000	1,500
38-2	240,000	1,500
38-3	190,000	300
S-1	<10,000	800
S-2	197,000	20,000
S-3	50,000	3,000
S-4	153,000	330
S-5	43,000	12,500
S-6	130,000	5,700
S-7	67,000	900
S-8	633,000	11,000
S-9	90,000	3,100
S-10	463,000	13,000
S-11	90,000	1,300
S-12	3,300,000	131,000
S-13	347,000	63,000
S-14	1,030,000	6,300

Bacterial numbers (which include Streptomycetes) vary between $1x10^5$ and $4x10^5$ per g in the profile. Fluctuations in the profiles (Soil Pits 29 and 38) are small, with the highest numbers appearing in the second depth (between 4 and 20 cm).

Fungal numbers in the profiles varied from 10^2 to 10^3 per g. Considerable differences are evident in the surface versus subsurface counts (samples S-1 to S-14). The surface 1 cm layer consistantly had a one to two orders of magnitude more fungal numbers than the subsurface layers. The same trend is also evident with bacterial counts.

Bacterial numbers in the soil profiles are lower by about an order of magnitude than those of the North American deserts. However, the tendency for higher numbers in the 4 to 20 cm soil levels is similar to American deserts.

Fungal numbers in the profiles are very low, averaging 10^2 per gram of soil.

Examination of some surface soils indicates that there are more micro-organisms, especially fungi, in the hummock (nebka) soil, under canopies of the desert flora (S-2, S-5, S-12) and in the loose sand among annuals (S-8). There appear to be lesser numbers in an apparently "young" pavement (S-6).

Fragments of several types of soil surfaces were incubated at 100% moisture and with illumination. At least one green algal species and one blue-green were observed on the surface of the "pavement" areas, but the growth appeared sparse.

Prolonged incubation produced sparse green algal growth, but showed considerable fungal proliferation, including appearance of aereal fruiting bodies. Nitrogen fixation by blue-green algae, a most important facet of the nitrogen cycle in American deserts, has not been examined at the Dar ez Zaoui site. More important was the elevated fungal activity within surface layers. It is likely that fungi are instrumental in stabilizing "pavements" in sandy areas.

Crusts: Various types of crusts were collected in July 1974 and examined for microbial content including bacterial differential. Additional crusts were collected in November 1974 and in May 1975 and examined for fungal components.

Alternaria seems to be very important in all the crusts and soils at the site. This is possibly due to its dark pigment. Dark pigments have been found to be important in screening out ultraviolet light which can be intense on the desert floor. Other fungi with darkly pigmented spores and/or mycelium were found to be important in desert systems because of this protective aspect. This is evident in the crust samples in which Phialomyces (with dark pigmented spores), Bipolaris (dark spores and mycelium) Alternaria (dark spores), Parodiella (dark perithecium), and Stachybotrys (dark spores and mycelium) are the prevalent genera.

Algal colonies appeared only in the crust with black spots and no vegetation after a week of incubation in light. Upon microscopic examination, the blue-green alga found to be present in high numbers was Oscillatoria and the green alga present although in low numbers was Oocystis.

Under-the-canopy (rhizosphere) samples: Soil samples from underneath four plant species were collected November 1976:

C-1 Retama raetam, 20-40 cm detph
C-2 Hedysarum spinsissimum, 0-20 cm
C-3 Argyrolobium (syn. Genista) uniflorum, 0-20 cm
C-4 Artemisia campestris, 0-5 cm

The samples were examined for microbial numbers and species differentiation.

There was no significant difference in numbers of total aerobic bacteria and streptomycetes between all four samples. Even though C-1 is a depth sample, the microbial numbers are still as high as surface samples, probably because of the rhizosphere effect of the roots. Fungal numbers, however, were one order of magnitude lower in sample C-1 than in the other samples. Proteolytic and carbohydrate-utilizing organisms showed very little response to the different plant species but lipolytic and chitinolytic organisms were much greater under Artemisia campestris.

Corynebacterium, Pseudomonas, and Acinetobacter are important in samples C-1, C-2 and C-3. In sample C-4 Corynebacterium and Serratia marcescens appear as the major bacterial species.

The major fungal species include Alternaria, Fusarium, and Cladosporium. In C-4 Cladosporium, Alternaria, and Monilia are important.

In general, Artemisia campestris seems to have the greatest effect on the microbial activities under its canopy. However, at this time there are not enough data available to make specific evaluations of the effects of these plant species.

Oasis soils: Of the collected oasis soils, a sample from the El Hamma oasis was examined for microbial numbers and differentiation.

In comparing the oasis sample with site samples, it was found that most of the groups of organisms were more abundant in the oasis soil by an order of magnitude. This increase is probably due to the increased organic matter and moisture content of the oasis soils. Fungi and carbohydrate utilizers show the least amount of change between the site and oasis soils. Both are lowest in the treatment (TM) controls.

Anaerabic bacteria showed the greatest increase (10^2 to 10^4 organisms per gram of soil). This is probably due to the increased moisture and campaction of the soil creating more anaerabic conditions. Proteolytic and lipolytic organisms were greater in the oasis due to increased substrate. Streptomycetes also show an increase in the oasis samples.

Microbiology of soil treatment plots at Dar ez Zaoui.-- The treatment schedule was described in a previous section. Samples from selected plots, collected July 1974, November 1974, May 1975 and December 1975 were examined for microbiological characteristics.

In the samples collected in 1974, total aerobes were slightly higher in TM-8 than in either of the palm-leaf-treated plots (TM-5 and TM-15). There was no significant change in streptomycete numbers or the physiological groups except for the carbohydrate utilizers. This group was one order of magnitude fewer in TM-15 than in plots TM-5 and TM-8. Plot TM-15 had loose sand with some plant cover. The carbohydrate utilizers were also lower in the TM-11-13 control site which has the same conditions of loose sand and plant cover as plot TM-15. These conditions appear to be slightly inhibitory to this group of organisms.

Fungi are slightly higher in the palm-leaf-treated plots than in the wood-shavings area. Fungi would be important decomposers of both these materials. However, fungi have been found in previous studies to be more numerous in loose and moving sand surfaces. Both the palm-leaf-treated sites are loose and moving sand, and this may be the reason for the higher numbers.

Pseudomonas and Corynebacterium are the major genera of bacteria in the treatment and control samples. Arthrobacter, Bacillus and Myxobacter also appear in the treatment samples.

Alternaria and Fusarium appear as the major fungi in the treatment and control plots. At this early sampling the fungal genera do not seem to be affected by the different materials added to the soils.

In the May 1975 samples, the total aerobic bacteria were generally higher in the treatment plots than in the controls. Fungi were again higher in the loose sand areas except for plot TM-11, which was treated with manure. Plots TM-5 and TM-4/5 control both show a decrease in numbers of streptomycetes and physiological groups. Both are sand dune plots. None of the other treatment plots or control plots show any significant differences in numbers of streptomycetes or the physiological groups. Since the limiting factor in this system is moisture, the various treatments do not seem to have much effect on microbial numbers.

In December 1975, there was an increase in numbers of total aerobic bacteria in all plots (10^6 per gram of soil). These samples were taken after the rainy season, and showed a response to increase in moisture content of the soils. The fungi also increased in both treatment and control plots. Streptomycetes showed a slight response to the moisture. There was little variation between the various treatment plots. All showed response to moisture, but no significant response to the amendments. The urea was most likely used up very rapidly when first applied, and has since had no effect on the microbial populations. Residues such as palm leaves and wood shavings which are more difficult to decompose, do not seem to provide the substrate needed for a quick response when moisture is made available. Of the fungi isolated from TM-13 in December 1975 soil 29 % were identified as Phoma. This is a wood saprophytic fungus which is not common in soil.

This plot received wood shavings as a treatment in 1973.

The control samples show some fluctuations since 1974. These slight changes are probably due to moisture conditions. The greatest fluctuation occurs in total aerobic bacteria and fungi. Streptomycetes are less affected by moisture than the other groups. This same situation occurs in other desert systems, where streptomycetes have been found to be relatively resistant to changes in moisture content of soils. Proteolytic organisms and carbohydrate utilizers remained relatively unchanged, while lipolytic organisms decreased. The latter have generally been the least significant group of organisms in this ecosystem.

Arthrobacter, *Pseudomonas* and *Corynebacterium* appear as major genera in all the sampling dates. In May 1975 *Proteus* and *Bacillus* are prevalent and *Micrococcus roseus* appears in the fall samples. It is noteworthy that ants were found to be carriers of *Micrococcus* (Johnson, 1973).

Alternaria and *Fusarium* are major fungal genera in all the sampling dates. *Stachybotrys* is prevalent in the 1975 samples, and *Mortierella* appears in the fall samples of each year.

Cultivation comparison site at Dar ez Zaoui.-- The cultivation comparison plots (F samples) were taken from national forest land that had been treated with various methods of cultivation. There was no significant difference between any of the F plots in microbial numbers in each of the different groups. The same was true in the F samples collected in December 1975. The various culitvation methods do not appear so far to have effected any changes in the microbial populations. Total aerobic bacteria were higher in December 1975 than in 1976, but the same thing occurred in the TM controls and was probably due to moisture conditions. Both the F treated and F control plots show *Micrococcus*, *Serratia marcescens*, and *Corynebacterium* and *Arthrobacter* as dominant organisms.

The fungal genera do seem to be affected by the various treatments in the F plots. *Penicillium*, *Alternaria*, *Fusarium* and *Cladosporium* were prevalent in F-1 (disced with stubble left intact). *Fusarium* and *Ulocladium* were prevalent in F-2 (traditional plowing iwth stubble grazed). In F-3 (disced with stubble grazed) *Penicillium* and *Mortierella* were prominent and in F-4 (traditional plowing with stubble intact) *Cephalosporium* and *Stachybotrys* are dominant. In both the F control plots *Alternaria*, *Cladosporium* and *Fusarium* were the dominant genera.

Effects of grazing at Dar ez Zaoui.-- The data on microbial analysis (Table 16.11) show a comparison of the numbers of microorganisms in the physiological groups studied for the grazing transect sites. These sites are a transect through ungrazed Dar ez Zaoui research enclosure to grazed land outside the enclosure fence as described above. All the physiological groups (proteolytics, chitinolytics, lipolytics, and carbohydrate utilizers) showed higher numbers in the ungrazed areas than in the grazed areas for both surface and depth samples. Lipolytic organisms seem to be the least significant group. The chitinolytic organisms are significantly

Table 16.11

Numbers of Microbial Groups in Grazed and Ungrazed Areas in Vicinity of Dar ez Zaoui, November 1976

	No. Organisms/g Soil by Grazing Treatment and Soil Depth			
	Grazed Sites[1]		Ungrazed Sites[2]	
Physiological Group	Soil Surface	20-40 cm	Soil Surface	20-40 cm
Proteolytic organisms	1.4×10^5	6.7×10^4	2.8×10^5	1.3×10^5
Chitinolytic organisms	2.3×10^4	9.1×10^3	1.1×10^5	4.3×10^4
Lipolytic organisms	3.7×10^3	9.8×10^2	7.9×10^3	2.4×10^3
Carbohydrate utilizers	2.2×10^4	2.4×10^4	4.3×10^4	6.8×10^4
Total aerobes	3.3×10^5	3×10^5	3.1×10^5	1.9×10^5
Streptomycetes	1.2×10^5	8.9×10^4	7.3×10^4	6.9×10^4
Anaerobes	3.8×10^3	9.6×10^2	5.7×10^2	2.9×10^3
Fungi	8.4×10^3	2.1×10^3	3.4×10^4	7.6×10^3

[1] Averaged values for plots TS-1, TS-2, TS-4

[2] Averaged values for plots TS-11, TS-13, TS-14

greater in the ungrazed sites by an order of magnitude, especially in the surface sample.

The total aerobic bacteria showed no difference between the ungrazed and grazed areas.

Streptomycetes were the only group that showed significantly greater numbers in the grazed than in the ungrazed sites. Because of their mycelial growth, streptomycetes function in binding soil particles together just as do fungi. They seem to be important in this disturbed, grazed area. Fungal numbers are greater in the ungrazed areas than in the grazed; however, this does not necessarily mean that the streptomycetes are more important than the fungi in the grazed area. The larger biomass of the fungi may still make them the most important soil binders.

The dominant bacterial species for both the grazed and ungrazed sites included *Acinetobacter*, *Corynebacterium*, and *Pseudomonas* species. *Pseudomonas* was the dominant organism in the depth samples for both the ungrazed and grazed areas.

The dominant fungi in the grazed-area surface samples were *Alternaria*, *Fusarium*, *Stachybotrys*, and *Chaetomium*. The grazed-area depth samples showed a very diverse distribution of organisms, with *Chaetomium*, *Trichocladium*, and *Fusarium* the major genera. The ungrazed-area surface samples were dominated by *Alternaria* and *Cladosporium* species, while the depth samples had an abundance of *Penicillium* and *Aspergillus*. Binet (1973) also found that in the Saharan Desert at depths below 5 cm, *Aspergillus* and *Penicillium* species are dominant fungi.

Microbiology of Henchir es Siañe soils.-- The first samples from the grazing parcels were taken in May 1975. There were no significant differences in numbers of aerobic bacteria or fungi among the plots. However, streptomycetes were about one order of magnitude more numerous in the depth samples of all the plots than in the surface samples.

In December 1976, the samples again showed essentially no differences in numbers of aerobic bacteria, streptomycetes and fungi when comparing all of the plots. Fungal numbers were more numerous than in the May 1975 samples by an order of magnitude, but the aerobic bacteria and streptomycetes showed no significant increase.

Analysis of microbial species was done on parcel H-II for both surface and depth samples. In the surface samples *Corynebacterium*, *Serratia marcescens*, and *Bacillus* appear to be the important organisms, while the depth samples showed a predominance of *Pseudomonas* and *Bacillus*.

The fungal genera are very diversified in these parcels. *Alternaria*, *Drechslera*, *Stachybotrys*, *Gilmaniella*, and *Cladosporium* appear as major genera in the surface samples. Over 80% of the species in the depth samples of H-II and H-III are *Penicillium*.

On parcel H-I several plots were established with different cultivation treatments. Samples from these plots were taken in December 1975 and November 1976.

The 1975 samples showed a general increase in numbers of total aerobic bacteria. This was most likely due to the higher moisture content of the soils at that sampling date. There was no significant difference between the plowed and disced plots and the control for aerobic bacteria, streptomycetes or fungi.

In 1976 the total aerobic bacteria decreased by an order of magnitude (from 10^6 per gram of soil to 10^5 per gram of soil) in both the cultivated and control plots. This was a response to the lower moisture content of the soils, as the rainy season had not yet arrived. The streptomycetes and fungi showed no such decrease, but they are usually less affected by changes in moisture availability.

There was again no significant difference between the cultivated plots. However, the plots with stubble (both traditional plowing and disced) had slightly higher microbial numbers for all groups (i.e. 5.0×10^5 in stubble plots and 3.2×10^5 in non-stubble plots for aerobic bacteria). This small increase in numbers is probably due to the added organic matter. The most significant increase was observed in the carbohydrate utilizers, which showed about a one-order increase. Overall there are still no significant changes in microbial status between any of these plots. Fusarium and Penicillium appear as major fungal genera in most of the cultivated and control sites. Alternaria, Stachybotrys, Cladosporium and Mortierella are also prevalent. These samples were taken at depths of 0-20 cm, and the non-pigmented fungi have become more important at these depths than they were on the surface.

Conclusions

The microbial numbers and the rates of associated biochemical activities in Tunisian soils are considerably lower than those of North American desert soils. The activities and numbers are dependnet on the available substrate (organic matter) either from the plant litter and root systems of higher plants, or from autotrophic C and N input by algae. The dependence on available substrate from plant sources was demonstrated in comparing the continuously grazed and ungrazed (research site) transect soils, where the microbial numbers were higher in ungrazed soils, reflecting the plant litter availability. This was reflected also in increased biological activitiies. Autotrophic C and N input by the green and blue-green algae appear minimal. The higher activitiey response in soils collected during the rainy period was evident.

The PreSaharan desert soils contain very little clay. Consequently, the cation exchange capacity was strikingly dependent on organic matter content. The organic (humic) matter content in these soils is extremely low and so is the ammonium retention facility. The values for fixed and exchangeable ammonium in these soils was drastically lower than the U.S. desert soils, generally containing higher amounts of clay.

It appears that any available organic matter is decomposed within a season in the PreSaharan desert soils with a subsequent loss of nitrogen during short, but favorable climatic (wet and elevated t^o) conditions. More than in any other desertic situations it is apparent here that next to water availability nitrogen is the main limiting factor for plant growth and biological activities in general.

The sparse vegetation constitutes essentially the sole input of organic matter into the soil. When moisture is available, respiration rates are high and decomposition is quite rapid. Therefore, very little organic matter accumulates in the soil and since clay is absent, cation exhange capacities, due entirely to the presence of organic matter, are low. The resulting poor nutrient retention properties serve to limit vegetation further.

Soils ammended with nitrogen (urea) and organic matter (i.e. wood shavings, manure, and palm leaves) showed increased nitrate levels over a short period but were non-effectual in the long term. Organic carbon (humic matter) levels as well in the treated soils did not remain higher than controls for extended periods. Loose sand treatment areas appeared the most productive in terms of microbiological activities and increased nutrient content over control soils. It is probably due to the increased plant growth and, consequently, increased litter input.

Generally, there have been no important changes in the microbial picture in any of the treatment soils or soils at different cultivation practices. The most drastic effect was seen in the grazed and ungrazed transect sites.

The response of desert microorganisms to treatments applied seems to be very weak. However, since moisture availability is a limiting factor in this ecosystem it may take years to determine the real effect of amendments on the microbial population. The organisms can only respond effectively at the short periods when moisture is available.

These studies have shown general characteristics similar to those found by other investigators of Saharan and U.S. desert soils. One was a surprisingly low number of spore-forming bacteria. *Bacillus* species were seldom prevalent in any of the plots analyzed. Fungi with darkly pigmented spores, mycelium, and ascocarps were found to be very prevalent, especially in the surface areas.

Fungi and streptomycetes appear to be the important organisms in desert systems. Their mycelial growth and larger biomass enable them to come into contact with more available moisture and to bind the sand particles, forming crusts and pavements which may enable N_2-fixing blue-green and green algae to become established.

Due to the inherent logistic and financial limitations of the project in sampling procedures and subsequent analyses, most of the information obtained does not yield to rigorous statistical analysis. The qualitative interpretations of the obtained results on the biological and biochemical state and processes, however, are consistent with our knowledge of the physical properties of these soils, vegetation and climatic conditions.

Detailed biological-biochemical examination of such soils has been most limited previously (Brown, 1974), and the emerging picture on these paraemters support other aspects of the analysis of this ecosystem.

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CHAPTER 17

STUDIES ON THE IMPACT OF DIFFERENT LAND-USE MEASURES ON THE ECOSYSTEM

by Geroges Novikoff

Desert Encroachment Studies

Principles of land reclamation for desert-encroached areas.-- The basic principle for reclaiming cultivated or grazed lands which have been degraded to the point of desert encroachment have been thoroughly described by Zingg (U.S.D.A., 1957), by the techniques used in grape orchards (S.C.S., 1963), by Boudet (1975), and by our own preliminary studies reported in Progress Report No. 5 (1976). In essence, soil movement is stopped by leaving a sufficient amount of vegetal mulch at the soil surface to prevent soil-particle movement. That mulch can be of different origins: litter left at the soil surface, anchored plant residues, or branches cut into fragments.

In terms of aerodynamic studies, this mulch increases the rugosity coefficient of the soil surface. As explained by Dr. Gillette of the National Atmospheric Laboratory at Boulder, Colorado, the mulch increases wind-speed threshold at which the soil particles creep at the ground surface. In other words, the critical windspeed for which the soil particles begin to creep is increased.

In order to apply these principles to Tunisian conditions, studies of soil movement under different cultivation patterns were begun in 1976, continued in 1977. The initial results of these studies are summarzied below.

Experimental design.-- Two blocks of four plots each -- one in Dar ez Zaoui and hereinafter termed "DZ", and one in Henchir es Siane, hereinafter referred to as "HE" -- were established according to the following treatments:

(1) Treatment 1: Polydisc plowed, grain stubble left in place after harvest (Plots DZ_3 and HE_1).

(2) Treatment 2: Polydisc plowed, grain stubble uprooted and removed after harvest (Plots DZ_1 and HE_3).

(3) Treatment 3: Traditional plowing with camel, grain stubble left in place (DZ_4 and HE_2).

(4) Treatment 4: Traditional plowing with camel, grain stubble uprooted and removed (DZ_2, HE_4).

Seed was sown in each plot at the same rate, namely 3 kg per plot (or a rate of 18.75 kg/ha). Soil catchment ditches were dug around each plot and the plastic linings shown in the 1976 report (Progress Report No. 5) were replaced with concrete linings.

Grain yields.-- Yields obtained from the two plowing methods, in terms of both grain and straw, are summarized in Table 17.1 for the two research sites.

Table 17.1

Grain and Straw Yields from Sample Plots Subjected to Different Plowing Methods

Site and Year	Kg/Ha of Grain by Plowing Method		Kg/Ha of Straw by Plowing Method	
	Polydisc	Traditional Plow	Polydisc	Traditional Plow
Dar ez Zaoui, 1975-76	100.8	4.5	180.0	16.3
Henchir es Siane, 1976-77	18.7	1.9	67.5	37.5
Means	59.7	3.2	123.7	26.9

Two patterns are evident in these data. One is the higher yields in 1975-76 than in 1976-77, undoubtedly a function of the very high rainfall in the first year, and the below-normal occurrence in the second.

The second pattern is the consistently higher yields from the polydisc plots than from the plots plowed by traditional methods. This might be explainable for Henchir es Siane by the fact that the plots were placed in an area with a large number of mature *Artemisia campestris* plants. The traditional plowing failed to uproot many of these and consequently many large *Artemisia* plants were present in the grainfields. These plants may have competed severely with the grain for moisture, particularly in rainfall-deficient 1976-77.

However, this competition hypothesis cannot explain the Dar ez Zaoui difference where *Artemisia* was not a problem. An alternative hypothesis is that the polydisc plowing creates a better soil mulch than the traditional plow, thereby reducing soil-moisture loss through evaporation. Soil-moisutre measurements will be made in 1977-78 to test this hypothesis.

Soil losses.-- The sand blown into the cemented ditches was removed and weighed after May 1977, and the data for Henchir es Siane are presented in Table 17.2.

Because of the poor yield resulting from the low 1976-77 rainfall, the amount of stubble left on the ground was actually insufficient to provide a good cover against wind erosion. Hence substantial soil loss occurred on all plots.

Treatments 2 and 3 have a much lower soil loss than Treatments 1 and 4. This may be due to microtopographic conditions: 2 and 3 are located in a slight depression which may reduce wind speed. In order to check this possibility, a supplmentary plot (HE_5) was added whose location is at the same level as HE_1 and HE_4. Windspeed recorders will also be set in these two different locations.

Fertilization trials.-- According to Dr. Wagner's suggestion (see Interpretive Summary,Progress Report No. 5), two additional experimental plots were added:

(1) One at Henchir es Siane (HE_6) in which chemical fertilizers will be incorporated into the soil at the growth stage when the barley tuft increases its diameter.

(2) One at Dar ez Zaoui (DZ_5) in which sheep and goat manure was added to the soil at the rate of 20 tons per ha. This manure is treated by placing alternate layers of sand and feces in a large trench and watering them. The weight of the sand crushes the feces into a powdery dust.

Grazing Studies

Application of Dyksterhuis range-condition and trend criteria to the Rhanterium suaveoleus ecosystem.-- The Dyksterhius scheme (1949, 1952, 1958) classifies plant species according to their response to grazing. Three categories of species are recognized:

(1) Decreasers: Species which decrease in production and density under moderate grazing intensities.

(2) Increasers: Species whose production and density increase under moderate grazing as the decreasers decline.

(3) Invaders: Species which increase after prolonged, intensive grazing.

Vegetation studies at Dar ez Zaoui allow a number of the plant species to be placed provisionally in these categories on the basis of their density changes since the beginning of the study. One experimental area was excluded from grazing in 1972 and has been kept in this status since that year. A second area (designated Pasture Cl, in Chapter 2) has been subjected to moderate grazing from the middle of spring to mid summer each year by a mixed flock of sheep and goats.

Table 17.2

Sand Accumulations in Trenches Surrounding Henchir es Siane Plots Subjected to Different Cultivation Treatments

Sampling Dates	Treat. 1 Polydisc, Stubble Left	Treat. 2 Traditional Plow, Stubble Kept	Treat. 3 Polydisc, Stubble Up-rooted	Treat. 4 Traditional Plow, Stubble Up-rooted
26th May 1977	1402	731	428	1073
10th July 1977	391	279	146	253
10th August 1977	101	58	91	188
12th September 1977	475	228	78	194
Total per Plot (Tons/Plot)	2.37	1.30	0.74	1.71
Total Soil Loss per Hectare (Tons/Ha)	14.80	8.10	4.64	10.67

Production and density measurements of a number of species were made in 1975 and are shown in Table 17.3. On the assumption that the abundance of each plant species was similiar in the ungrazed area and in C1,prior to the beginning of grazing treatment, and that differences between the two areas are now due to grazing or the lack of it, the species were grouped into those which were more abundant in the ungrazed area and considered to be decreasers; those which were more abundant in the grazed area and considered increasers; and the single, highly weedy species, Artemisia campestris, which is considered an invader. In addition, the dominant Rhanterium suaveolens is considered to be climax and is included among the increasers.

Concepts of range condition and trend in range management.-- The objective of a range management program is either to improve deteriorated range or allow a range in good condition to remain in that state. To reach these goals, the evaluation of range condition and trend are necessary.

Range condition: The condition of the range is sometimes defined (U.S.D.A. Handbook, 1962, p. 8) as the state of health of a range site at the present time. That state is normally considered to be the production of a site expressed as a fraction of the potential for the site. This provides a means for classifying range sites and indicating to the farmer the sites from which he will get the quickest return on his investments (U.S.D.A. Handbood No. 235, 1962, p. 46). With such data it is possible to prepare a grazing management plan.

The criteria used to measure range condition of a grazing land are as follows:

(1) Present production expressed as a percentage of potential production. The latter figure is obtained from range sites excluded from grazing for several years.

(2) The percentage by weight of decreasers as compared to the total production.

(3) The percentage of soil sufrace covered by litter (or the amount of litter by weight).

(4) Erosion conditions: Percentage of soil covered with ripple-marks (wind erosion) or by rills or gullies, and their depth.

Range trend.-- In order to evaluate the correctness of past and present management programs, it is necessary to know the trend of the range condition. Knowing whether or not the vegetation is improving, deteriorating, or just stationary enables one to judge whether existing practices are correct or need to be changed. Range trend is determined by measuring the condition of the same site at different points in time.

Table 17.3

Tentative Classification of Dar ez Zaoui Plant Species in Dyksterhuis Grazing Category Based on Production Measurements in Nebka Subunit in Spring 1975

		Area Excluded from Grazing (A)			Area with Spring Deferred Grazing (C_1)		
Plant Species by Category	Age Class	Prodn. Kgs/Ha	% of Total Prodn.	No. Indiv. per Ha	Prodn. Kgs/Ha	% of Total Prodn.	No. Indiv. per Ha
Decreasers and Near Climax Species							
Rhanterium suaveolens[1]	Adults	58.8	11.2	2,900	61.1		3,100
	Seedlings	2.0	0.4	27,700	2.6		30,600
Argyrolobium uniflorum	Adults				3.9		1,200
	Seedlings	22.5		23,300	2.5		2,500
Helianthemum lipii var. sessili florum	Adults						
	Seedlings	2.2	0.6	5,600	Tr		200
Annuals							
Matthiola kralikii		98.2	18.0		53.5		
Daucus syrticus		31.6	6.0		1.8		
Zollikoferia resedifolia ssp. eu-resedifolia		23.1	4.4		8.3		
Hedysarum spinosissimum ssp. eu-spinosissimum		4.0	0.7		1.0		
Cutandia divaricata		217.3	41.6		55.7		
Total decreasers		466.8	89.4		200.4	69.6	
Increasers							
Asphodelus fistulosus		27.7	5.3		48.5		
Ifloga spicata		20.8	3.9		29.7		
Hordeum murinum		2.1	0.3		5.3		
Cleome arabica		0.2	0		2.1		
Total Increasers		50.7	9.7		85.6	29.0	
Invaders							
Artemisia campestris	Adults	2.6			1.1		
	Seedlings	1.7			0.8		
Total Production		521.7			287.9		

[1] Rhanterium suaveolens is considered a climax species in this ecosystem, hence its inclusion in the decreasers.

Conclusions.-- The Dyksterhuis classification sytem, in addition to use in the arid areas of the U.S.A., has been used in Afganistan and Brazil. It appears to have promise for the PreSaharan Rhanterium suaveolens ecosystem of Tunisia.

Effect of one summer grazing season on plant composition.--

Objectives: In order to evaluate the effect of summer grazing on plant composition, 15 exclosures were set in plot D_2 prior to summer grazing in 1976. In spring 1977, plant composition and production were measured with sample plots inside and outside the exclosures to measure the effects.

Results: Not all species can be reliably compared. Some are so scarce that samples are small and variances large. Included in this category are Astragalus gyzengis, Fagonia glutinosa, Pituranthos tortuosus, Lygaeum spartum and Gymnocarpos decander. However certain species and groups of species seem to have responded (Table 17.4).

The annuals and biennials as a group did not exhibit much difference, although two species -- Plantago albicans and Zollikoferia resedifolia ssp. eu-resedifolia, both highly palatable (see Crocker-Bedford chapter) -- were substantially more abundant in the exclosures.

The small-sized perennials were markedly more abundant inside the exclosures -- almost twice -- than outside. Much of the difference is attributable to the two most abundant species in the enclosures -- Argyrolobium uniflorum and Erodium glaucophyllum -- which were about three times as abundant in the protected areas. Argyrolobium is highly palatable to livestock.

Several of the larger shrubs and perennial grass species were markedly more abundant in the exclosures, particularly Stipa fontanesii and Aristida pungens.

Important features of PreSaharan pastures in the Rhanterium ecosystem.-- Precipitation for the past 5 years at Dar ez Zaoui have been as follows:

1972-73	15 mm
1973-74	94 mm
1974-75	186 mm
1975-76	497 mm
1976-77	69 mm

While this is a short series of years from which to generalize, 3 of the 5 have fallen below the 100 mm average for the locale. The years will hereinafter be termed "droughty" years.

Because of the frequent occurrence of droughty years in the PreSaharan region, a good pasture should contain not only maximum plant production in winter, but a maximum of plants which begin winter growth early in a droughty year so that there is high-quality forage for ewes during the

Table 17.4

Comparison of Plant Production by Annuals, Small-sized Perennials, Shrubs and Perennial Grasses in Summer-Grazed (D_2) and Ungrazed Areas of Dar ez Zaoui, 1976

Plant Species by Vegetation Type	Kg Dry Matter/Ha Inside and Outside Exclosures	
	Inside	Outside
Biennials		
Plantago albicans and Zollikoferia resedifolia ssp. eu-resedifolia	71.6	46.7
Other species	31.5	47.6
Subtotal:	103.2	94.4
Small-sized Perennials		
Argyrolobium uniflorum	52.5	17.5
Nolletia chrysocomoides	23.2	21.9
Erodium glaucophyllum	61.0	18.6
Linaria aegyptiaca	24.5	25.8
Helianthemum lippii v. sessiliflorum	12.7	10.1
Atractylis candida	10.8	8.1
Echiochilon fruticosum	6.5	3.1
Pituranthos tortuosus	0.6	
Fagonia glutinosa ssp. cretica	1.2	0.8
Astragalus gyzengis	Tr	0.1
Subtotal:	193.0	105.3
Shrubs and Grasses		
Stipa fontanesii	6.0	2.3
Aristida pungens	13.1	0.6
Lygaeum spartum	6.5	0.1
Gymnocarpos decander		0.3
Subtotal:	25.5	3.3

1-month period before lambing and during the month following birth. Such conditions are recommended by animal nutritionists in Tunisia.

Pasture B_2 is such a pasture because, as described in Chapter 2, of its extensive production of annuals,and the high composition of Plantago albicans and Zollikoferia resedifolia ssp. eu-resedifolia. Both begin growth early and are highly palatable. In Plot B_2 they make up 78% of annual and biennial production, 69.1% of C_1 nebka type, and 73.1% of C_1 normal soil-surface type. They are less abundant in other plots.

Argyrolobium uniflorum is also an early-growing, palatable species which is abundant in Pasture D_2 as well as B_2.

Years of average or above-average rainfall appear to favor extensive growth of annual legumes. This was evident in Pasture C, during 1975-76. These species appear to be important for livestock. Unfortunately legumes do not appear to be abundant in the same areas as Plantago, Zollikoferia, and Argyrolobium.

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CHAPTER 18

HUMAN USE OF THE PRESAHARAN ECOSYSTEM AND ITS IMPACT ON DESERTIZATION

by William H. Bedoian

Introduction

Productivity of the desert environment on the Saharan fringe varies greatly from year to year. Based on the experience of the Sahel drought and subsequent ecological collapse, the Saharan fringe seems to be easily upset by unwise human use under certain conditions. Specifically, when grazing and agricultural exploitation occur during periods of low rainfall, vegetation and soil stability are disrupted over vast areas. Without the vegetation to hold the soil, it is blown off the ground surface and deposited in dunes. In spite of such disastrous results, human populations continue to utilize the remaining usable land in ways which lead to desertization. Desertization is the "spread of desert-like conditions in arid or semi-arid areas due to man's influence or to climatic change" (Rapp, 1974).

In 1971, this project initiated ecological research on the structure and function of the PreSaharan ecosystem on the Saharan fringe in southern Tunisia. By including the human population in the ecosystem study, it was hoped that the reasons behind current land-use strategies could be determined. In addition, the extent of the human contribution to desertization would be assessed. In order to accomplish these objectives, a study of energy flow through the human population was undertaken in 1973-75. From the results of the ecosystem study, it was anticipated that less destructive land-use alternatives could be proposed which would be compatible with the subsistence needs of the local inhabitants. The adoption of such alternatives would reduce or halt the processes associated with desertization.

Energy-Flow Approach to the Study of Human Ecology

In one sense ecology can be thought of as the study of "any property that has a measurable direct influence on the fecundity, longevity, speed of development, or spatial position of an organism" (Maelzer, 1965). Environmental energy flow influences the nutritional status and spatial position of organisms and can be considered as an ecological factor which may elicit a population response. The biological and behavioral attributes of a population can be analyzed as responses to ecological factors. Such responses have a bearing on the survival, reproduction, development, or spatial position of individuals in the population (Little and Morren, 1976).

Some components of the environment can be considered limiting factors on the amount of energy available to and trapped by ecological communities. Rainfall and temperature are such factors in the Tunisian desert, where rainfall and vegetal growth occur during the winter. Energy flow itself can be a limiting factor influencing the biological and behavioral responses of a population. An interruption in energy flow threatens the survival of man and other organisms in the ecosystem. If energy flow is near the minimal level needed to support a human population then one would expect certain behavioral and biological responses which would maximize the production of energy or minimize the utilization of energy.

The study of energy flow can be used to evaluate the human exploitation of an environment. It is an especially useful approach for studying a population which derives most of its subsistence needs from the ecosystem in which it lives. One focus of this approach in humans is the family economy. Observations are made on the production of crops and animals, on dietary consumption of the food which is produced, and on expenditure of human energy in work tasks associated with gaining a livelihood. Attention is also focused on the extraction from the environment of products which are not part of the human diet. The harvesting of firewood, of plants for animal feed, of wood or branches for building material, and of other non-food items is studied in order to assess the total use of an ecosystem by the human population within it. The study of energy flow is a refinement of previous anthropological approaches dealing with the human economy because with it the investigator can compare the energy value of wage and subsistence labor with the energy value of crops and animal products and with the energy requirements of family nutrition. The energy value of crops produced can be evaluated as a function of energy spent in work efforts. This offers insights not provided by considerations of man-hours in subsistence pursuits, or by estimation of cash value of subsistence labor, or by evaluations of cash flow.

In such studies the energy produced or extracted from the local ecosystem is traced through the various pathways of deployment by the family. Nutritional needs of the family and its domestic animals are primary concerns in this deployment. The storage of any surplus energy is seen as a strategy to deal with annual variability in energy flow or economic production. The import and export of energy to and from the local ecosystem is also studied, as is the amount of wage labor performed by members of the population. A knowledge of the various transfers of energy enables one to assess the degree of dependence of the human population on the local environment for meeting human needs and wants.

The Value of Energy-Flow Studies fof Economic Planners In Developing Arid Regions

If a population cannot derive all of its needs from subsistence pursuits in the local area, it must depend on the import of food products to meet its needs. Human populations inhabiting arid lands are often characterized by some degree of reliance on domestic animal populations to furnish resources for the human economy. In such economies one often finds that semipastoralists convert animal resources into other goods (manufactured products, agricultural products, cash reserves) via some type of exchange or market system.

Energy-flow research provides a knowledge of the subsistence alternatives available in an area and provides an understanding of the ways by which the inhabitants decide between alternatives. Often these alternatives are based on the ability to convert from one resource to another via a market system of some sort. One of the basic strengths of the energy-flow approach is its ability to establish conversions or equivalencies between human labor (both subsistence effort and wage labor), money resources, agricultural and pastoral goods produced, and purchased food items. With this type of information it is possible to determine the relative costs and benefits of local food production versus food importation, of wage labor income versus income from the sale of animal and agricultural products, or of a reliance on one or another crop complex.

This approach is one of the few which enables the policy planner to treat unpaid agricultural and pastoral labor as a family resource. By determining the energy cost of various subsistence activities one gains a refinement which is not usually available from studies in economic anthropology. In calorie terms, man-hours are not equivalent to woman-hours or to child-hours. Each calorie of energy spent in subsistence tasks brings a certain return of energy in the crop harvested.

By simultaneously studying the deployment or investment of labor and material resources, one can assess the feasibility of potential economic development proposals which involve the use of land or labor in an arid region. If the population has a very limited margin of surplus resources, then it will be unable to survive a development program requiring that basic resources be set aside and invested rather than be used for a more short-term, direct gain to the family.

Economic Production In Southern Tunisia

Two aspects of material production must be considered when evaluating the effectiveness of population responses to the ecological constraints on subsistence production in southern Tunisia. The first is the average amount of goods produced by the family over a period of many years. A legitimate question is whether this average production is enough to sustain the needs of the population without additional input from other ecosystems. The second aspect of land use is the extreme variation in annual rainfall, and hence in economic production from year to year in southern Tunisia. The question then becomes whether agricultural and pastoral production is sufficient in excellent years to provide a surplus which can be stored and used in years of little or no rainfall. This question suggests very different expectations concerning the appropriate type of behavioral response on the part of the local inhabitants. Both the annual variation and the overall average production will be dealt with in this paper in an attempt to describe the stragegies enabling the population to persist over time in this area of southern Tunisia.

In southern Tunisia one encounters a sparsely settled population of relatively sedentary Arab families who engage in agricultural and pastoral pursuits to gain their livelihood. Formerly the population was more nomadic, and pastoral pursuits dominated the family economy. The economy presently includes widespread use of tractor services and human labor to produce barley, wheat and olives, and involves reliance on cash from the sale of male animals from family herds. In addition to the energy extracted from the local ecosystem, family resources are supplemented with cash earned by adult males performing wage labor in cities and towns in southern Tunisia and Libya. Males leave the ecosystem to earn a wage income during the portion of the year when agricultural tasks are at a minimum.

The location of the study area of the Tunisian PreSaharan project nad of the human energy-flow project can be seen in Fig.18.1 and 18.2. The sampling zone of the human energy-flow project was purposely centered around the study site of the Tunisian PreSaharan project. Rainfall is continuously monitored on the study site and values reported here are derived from those data. A questionnaire concerning agricultural production between 1972 and 1975 was administered to 24 families whose home base falls within the sampling zone. Information was obtained on the size of barley, wheat, and olive harvests; the number of olive trees owned; the number of animals sold and the resulting cash obtained; the amount of human and animal food purchased; the amount of income from wage labor; the amount of cash spent on tractor services; the deployment of agricultural produce to the family and herd. Average harvest sizes were converted to energy production estimates by using the caloric value of barley, wheat, and olive oil reported by Leung (1968).

Observations on human energy expenditure in subsistence tasks were based on working time per unit of crop produced. For instance the harvesting time for barley and wheat was recorded as minutes of work per kilogram of grain harvested. A sample of working individuals were observed for each task. The average harvesting time per kilogram of grain was then multiplied by the total harvest size in order to estimate the total harvesting time needed for the whole grain crop.

The total working time for each subsistence activity was converted to energy expenditure as follows. The heart rate of working individuals was obtained during the performance of subsistence tasks. The average heart rate for each task was converted to an energy expenditure value by measuring heart rate and oxygen uptake for a sample of males and females during an exercise test. The results provide a regression of caloric expenditure on heart rate which can be used to predict a specific energy expenditure rate from a given heart rate. Thus the field measurements and the questionnaire data were combined to provide estimates of average energy expenditure and production associated with each crop produced during the three-year study period. These averages form the basis of Fig.18.3,

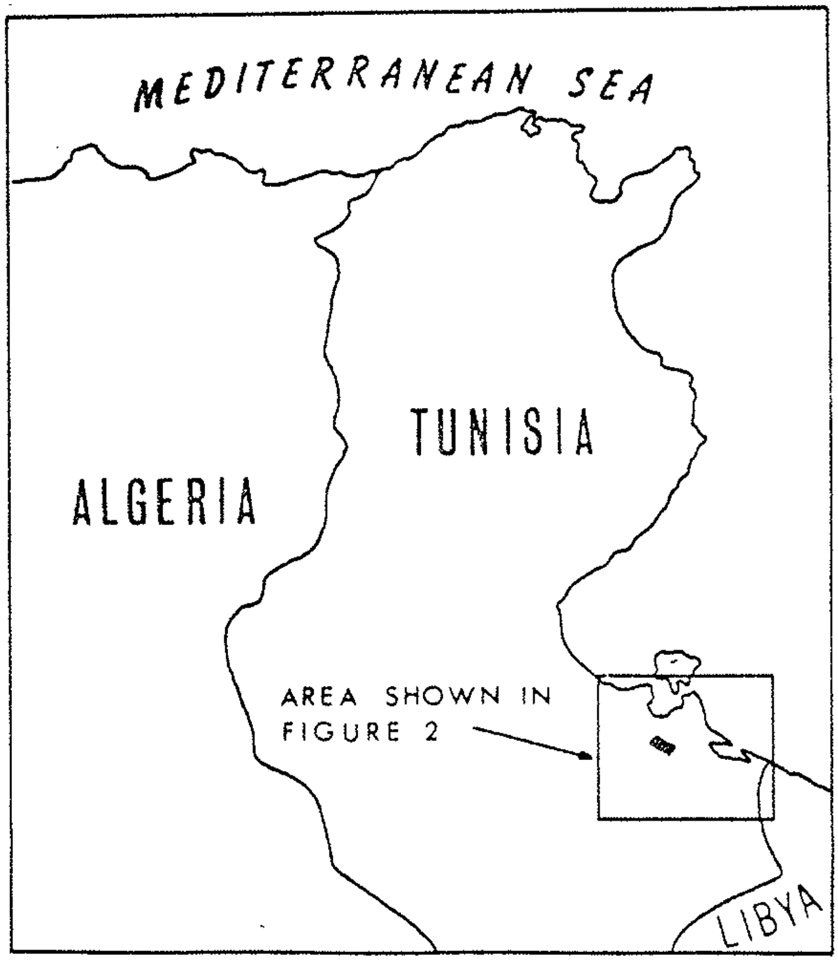


Figure 18.1. Location of study area in Tunisia

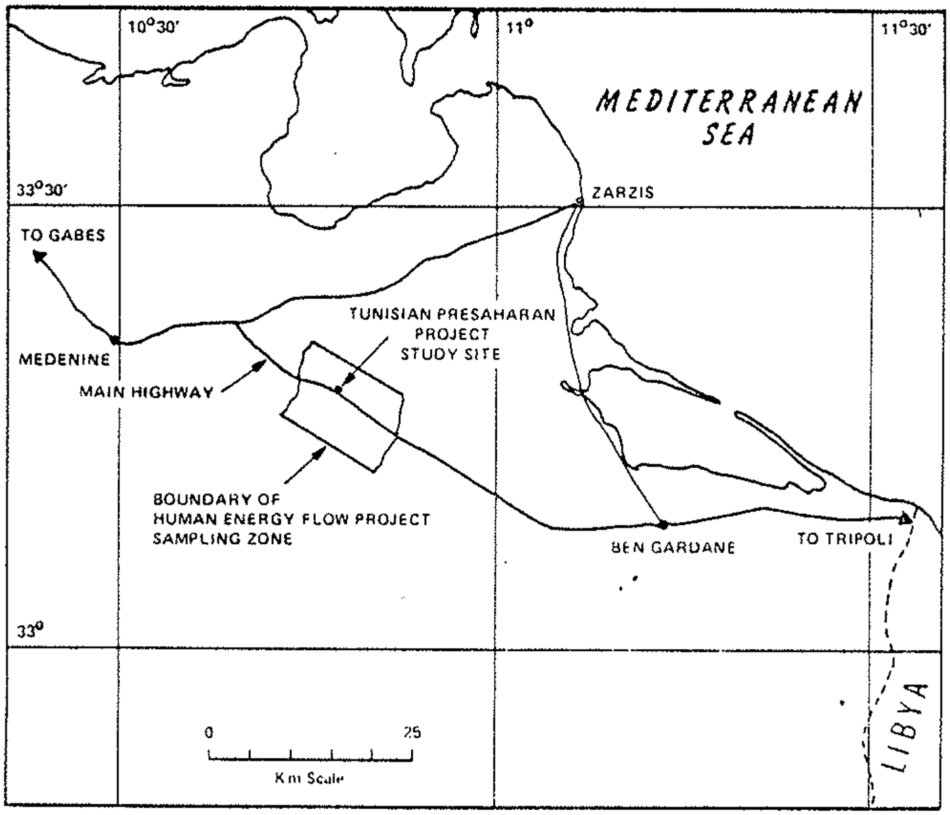


Figure 18.2. Location of study area in relation to the study site of the Tunisian PreSaharan Project.

.4, .5, and .7.

The sample averages derived from the questionnaire are used to characterize the average family. Such a family consists of two adults and four children. It uses 69 hectares of land near its home base in its economic endeavors. Of this, 14 hectares are owned and the rest are borrowed from absentee land owners who may also be relatives. In addition, the family owns 16 hectares of land in small parcels scattered throughout the PreSaharan zone of southern Tunisia. This land is used in years when rainfall on the home base has been inadequate for planting grain.

Economic production during a year of abundant rainfall (1974-1975)-- During the agricultural year 1974-1975 (fall 1974 through summer 1975), 186mm of rainfall was measured on the study site. Fig.18.3 is a schematic hcart of energy flow through the average human family and its herd for the 1974-75 agricultural cycle. In this diagram the flow of energy produced is read from left to right, and the paths and arrows indicate the deployment of energy produced. The energy values of all work activities needed to produce a particular crop have been combined into a single figure. This amount of energy is indicated by a vertical arrow leading to the work gate. The work gate symbolizes the work-energy input needed to produce the crop.

The producer organisms (plants) are grouped on the left, and the consumer organisms (grazers and humans) are grouped to the right. On the extreme right the exchange system is represented. The only purchased foods reported are those which make a large contribution to the caloric intake of the family. Items not reported are purchased in very small quantities each year or have a low caloric content.

The diamond-shaped symbols represent conversion of energy from one form into another. Much of the converted energy leaves the ecosystem as payment for mechanized services rendered. Therefore there are no arrows appearing beyond the conversion symbol. Cash derived from wage labor comes from outside the ecosystem as well so there is no arrow connecting it to the local energy-flow system. Cash income from wage labor and animal sales is used for the various expenses indicated in Fig. .3. There are no connecting arrows between the sources of cash and various points of expenditure in the system. These have been omitted to keep the diagram as simple as possible. There are no connecting links between straw produced andstraw consumed by the camel. Nor are there links illustrating the channeling of olive leaves and fodder to the camel. These omissions also make the diagram more readable.

Food energy consumed by the family has been indicated by heavy lines. Most of the energy consumed by the family is spent in basal metabolism or in social activities. This is not represented in the diagram. Only the energy associated with subsistence work is shown. It is channeled back into the productive system in the various subsistence tasks.

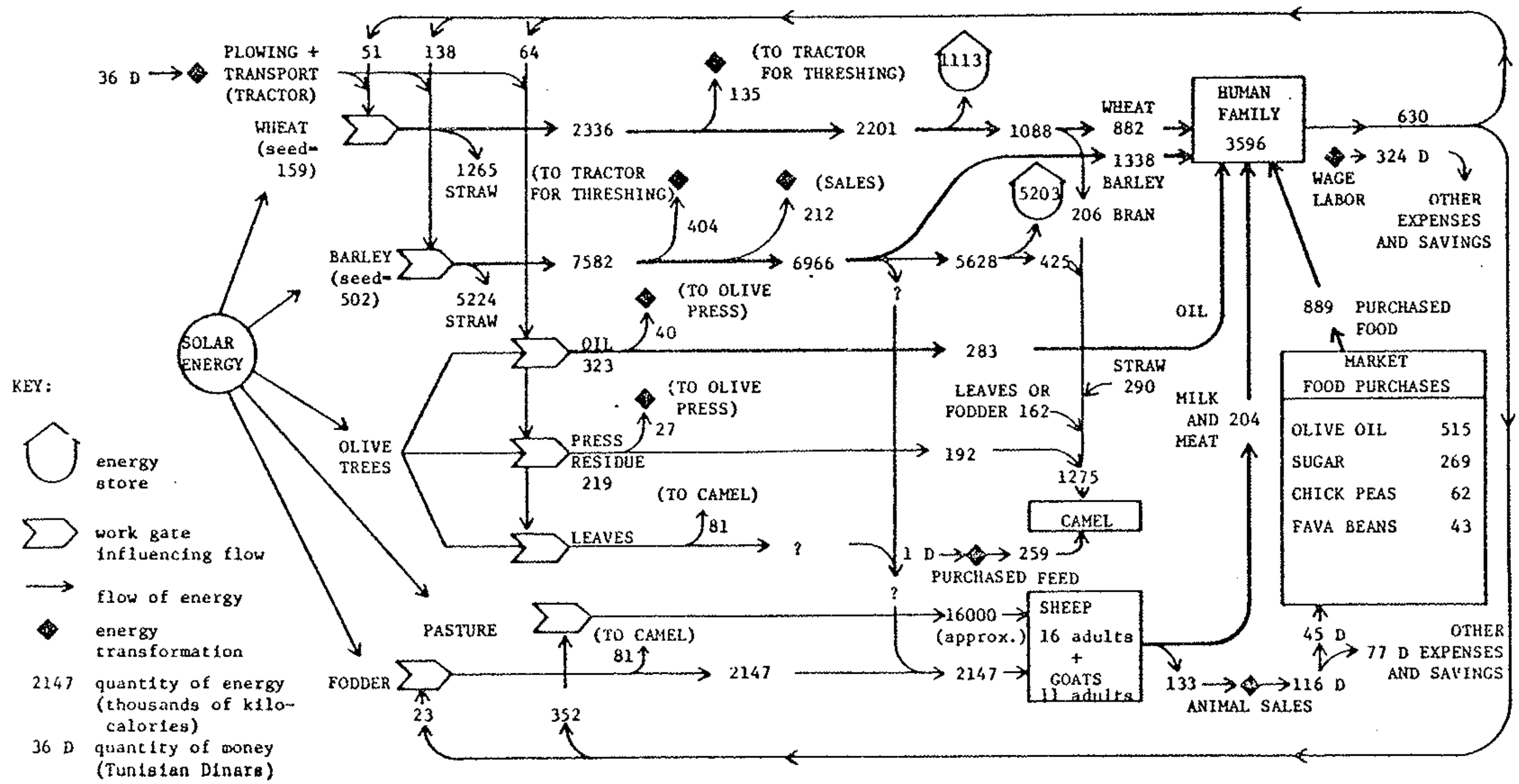


Figure 18.3. Energy flow (during moist 1974-75) through the average human family in the PreSaharan ecosystem.

Grain production: From Fig. 18.3 several inferences can be made concerning the adequancy of this particular year of agricultural and pastoral production for meeting family needs. The amount of grain produced was greater than the amount used in the family diet. Because of the abundant rainfall and vegetal growth, the herd only needed minimal food supplementation during late summer and early fall. It is likely that none of the animal diet supplementation was purchased. A considerable amount of grain was put into storage to be used during a year of poor rainfall. The family purchased both wheat and barley to obtain extra seed. This purchase was made because not enough seed was available from the family's grain reserves to take advantage of the abundant rainfall. A considerable amount of money was spent to engage a tractor to assist in this planting.

Olive production: The production of olive oil was clearly below the average family's annual need. Olive yields respond to rainfall occurring 1 year prior to the winter harvest, so that the yields of December 1974-January 1975 were a reflection of poor rainfall the year before. A factor which tends to reduce olive crop yields is the presence during the spring of severe, hot, south-westerly winds (sirocco) originating from Sahara. These winds blow most of the olive flowers off the trees before they can set fruit. This, along with the below-average rainfall, probably was responsible for the mediocre olive crop in 1974-75. Poor olive production resulted in the purchase of substantial amounts of olive oil for family consumption during 1974-75.

Fodder harvest: Annual herbs and perennials were harvested in spring 1975 to be stored as fodder (khortan), and used as a dietary supplement for the herd during the late summer months. The amount collected in 1974-75 was about double that collected in each of the previous years. Because of abundant forage plants on the range land, it is possible that much of the fodder was not needed in 1974-75 and went into storage to be used during a dry year.

Cash income and expenses: Animal sales and wage labor produced a total cash income of 440 dinars in 1974-75. Considering routine costs of purchased food, tractor service fees, and other incidentals, only about 90 dinars of expenditures can be accounted for on the survey forms. This leaves an apparently large cash surplus during that year. However, since agricultural production was high in that year, the inhabitants arranged marriages, circumcisions, house building, and other social occasions which involved considerable expenses and food. Questions about such expenses were not included in the economic survey. In addition, families periodically use extra cash to buy up small parcels of available land adjacent to their home-base land holdings. A few families have considered purchasing a share in a tractor, which is a major expense involving hundreds of dinars. Although one might expect a family to attempt to build cash reserve in a good year, the major unaccounted expenses discussed above probably reduce that reserve substantially below what might be estimated.

In overall perspective, the 1974-75 agricultural cycle was the closest to a state of complete population support by the local ecosystem of any of the 3 years to be described. Of course, certain food items must always be purchased from outside of this ecosystem regardless of the productivity in any given year. But in the year just described, animal production was such that enough energy could be channeled into the exchange system to obtain those food items which could be produced locally. Grain production was sufficient to create a large reserve for use in a drier year.

Economic production during a year of near-average rainfall (1973-1974)--The beginning of the agricultural cycle in the fall of 1973 was delayed because of below-normal autumn rains. A sufficient rainfall occurred in mid-December but because of the short length of the subsequent growing season, the grain crop resulting from this late planting was poor. Total rainfall during the growing season amounted to 94mm. The average is around 100mm for this ecosystem.

Grain production: As shown in Fig.18.4, the grain produced in 1973-74 was substantially less than the normal amount consumed in a year. Large purchases of semolina helped to offset the effects of the poor wheat harvest. The amount of barley produced was also supplemented by purchases for family consumption as well as for the herds. The preceding year (1972-73) had been very dry, and apparently all previously existing reserves had been used to support the herds in that year.

There was 33% less barley and wheat seed planted in 1973 than in 1974. There was also a 50% reduction of cash expenditure for tractor plowing services compared to 1974. These trends reflect the diminished emphasis on grain planting as a result of the low rainfall. Families are less willing to invest in either seed or tractor services when they expect a drier-than-normal year. The poor rainfall in 1973 also forced families to look farther from their home base for some of their planting sites. The greater distance causes some inconvenience to the family. Recently, due to increasing availability of tractors, they have sometimes been willing to alleviate the inconvenience of plowing distant sites by engaging a tractor.

Olive production: Although rainfall was less in 1973-74 than in the next year, the olive crop was much better than 1 year later. As previously mentioned, the hot winds in spring have a confounding influence on the effects of rainfall on olive crop yields. Perhaps these winds were not severe in 1973-74. There was slightly less emphasis on tractor plowing services in the olive orchards during the drier year than during the following year. This was compensated by an increase in plowing with a draft animal.

Olive production in 1973-74 was still not at a level which could support normal family and herd needs during the year. The amount of oil purchased during the year was 35% of the amount consumed by the family. Olive meat press residue, which remains after the oil extraction process, is used as an animal food. All of the press residue fed to goats and sheep and 60% of the residue fed to camels in 1973-74 was purchased.

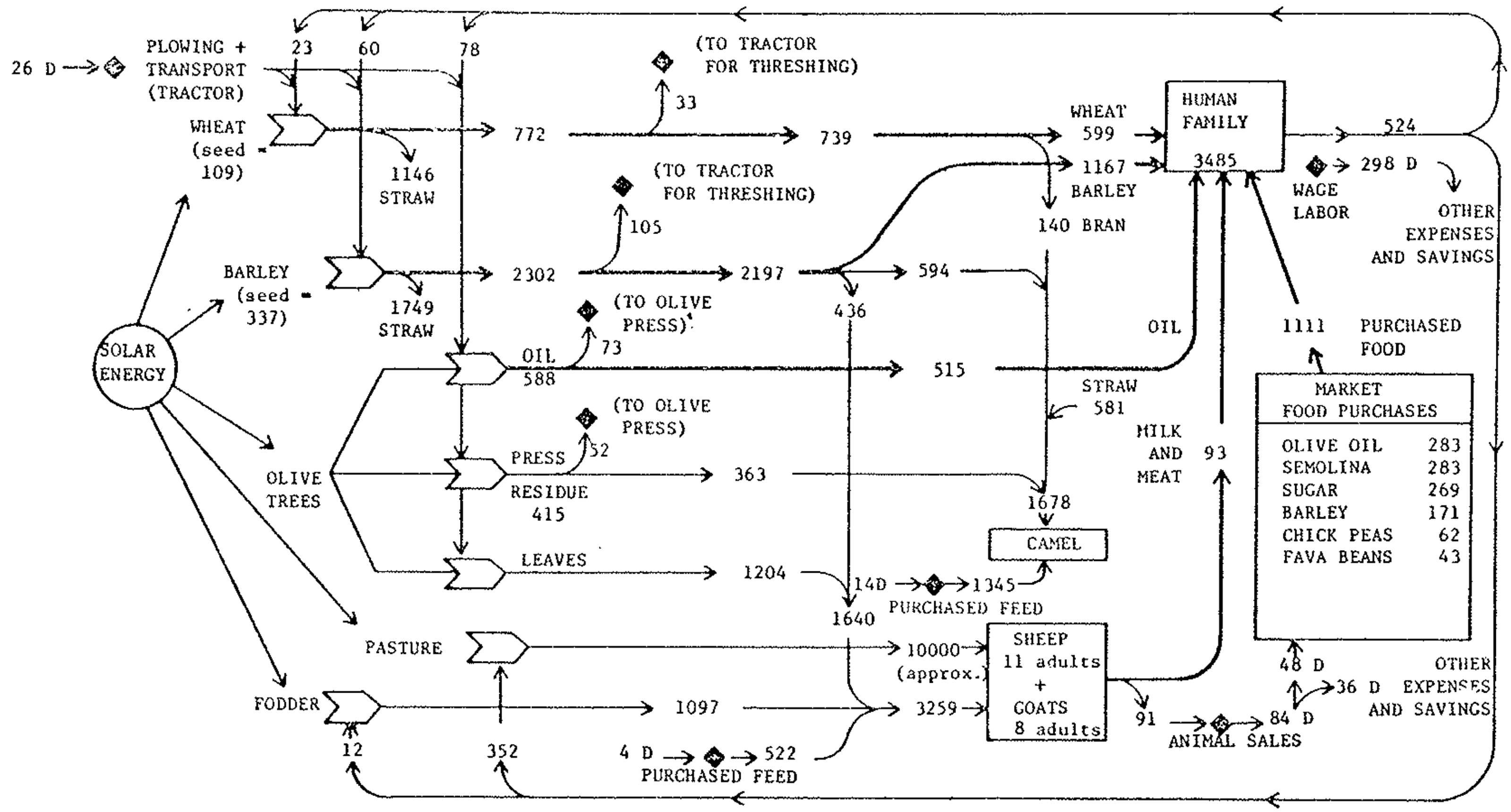


Figure 18.4. energy flow (during average 1973-74) through the average human family in the PreSaharan ecosystem.

<u>Fodder harvest</u>: The amount of annual herbs and perennials harvested in spring for use as summer fodder was 50% below the 1974-75 level. This was not enough to support the supplementary diet needs of the sheep and goats during the summer of 1974. Some 1 million kilocalories (kcal) of fodder and 2 million kcal of other types of feed were used to supplement the diet of goats and sheep. Perhaps 20% of the total, annual dietary needs of the sheep and goats were met by food not derived from grazing. However, most of this supplement was produced in some way on the home base and only a minimal amount of feed was actually purchased (less than 5% of the toal diet).

<u>Cash income and expenses:</u> Data on animal sales were not collected for years prior to 1974-75 because it was felt that the family head would not be able to recall earnings which occurred in previous years. Animals are sold by lots of 2 or 3 during the entire annual cycle, and unit prices change with the seasons. I suspected that such a pattern would be different to recall after a new annual cycle had already begun. In order to arrive at an estimate of income from animal sales prior to 1974-75, the family head was asked about the number of adult female goats and sheep in his herd during each of the two previous annual cycles. Adult females were counted because they produce newborn male animals which are the main source of income from animal sales. Total cash earnings from lamb and kid sales in 1974-75 was divided by the number of adult females owned in 1974-75. This factor (4.3 dinars per adult female) was multiplied by the average number of adult females in the herd for the years prior to 1974-75. In this way income from herd sales was estimated for 1972-73 and for 1973-74.

During the year each family earned an average of 298.4 dinars in wage-labor income. Animal sales produced as estimated 84 dinars, so that the total cash income was 382 dinars. During the same year, routine cash expenditures amounted to 97.6 dinars. A large part of the income was saved, probably as insurance against the effects of a future dry year. At the end of the agricultural cycle in 1973-74, the family had little or no grain, oil, or animal feed reserves. The family would therefore have been in a poor position to absorb the effects of a dry year if it did not have a cash reserve.

<u>Economic production during a year of low rainfall (1972-1973)</u>-- Rainfall during the 1972-73 agricultural year was a mere 15mm in the study area. By local standards, this was not enough to justify a large-scale,grain-planting effort on the home base land. Nevertheless, several families planted a small amount of grain on the home base with poor results. One third of the sample families planted no grain at all during the year. The remaining families planted grain only at distant locations where rainfall had been better. Thus, in spite of an extremely low amount of rainfall on the home base, many families were able to produce a modest crop by cultivating distant land.

<u>Grain production:</u> The schematic representation of energy flow during the 1972-73 year is illustrated in Fig. 18.5. The grain crop produced was the smallest of all 3 years for which data are available. However, purchased barley amounted to only 19% of the total amount of barley consumed by the family. The quantity of wheat purchased was also

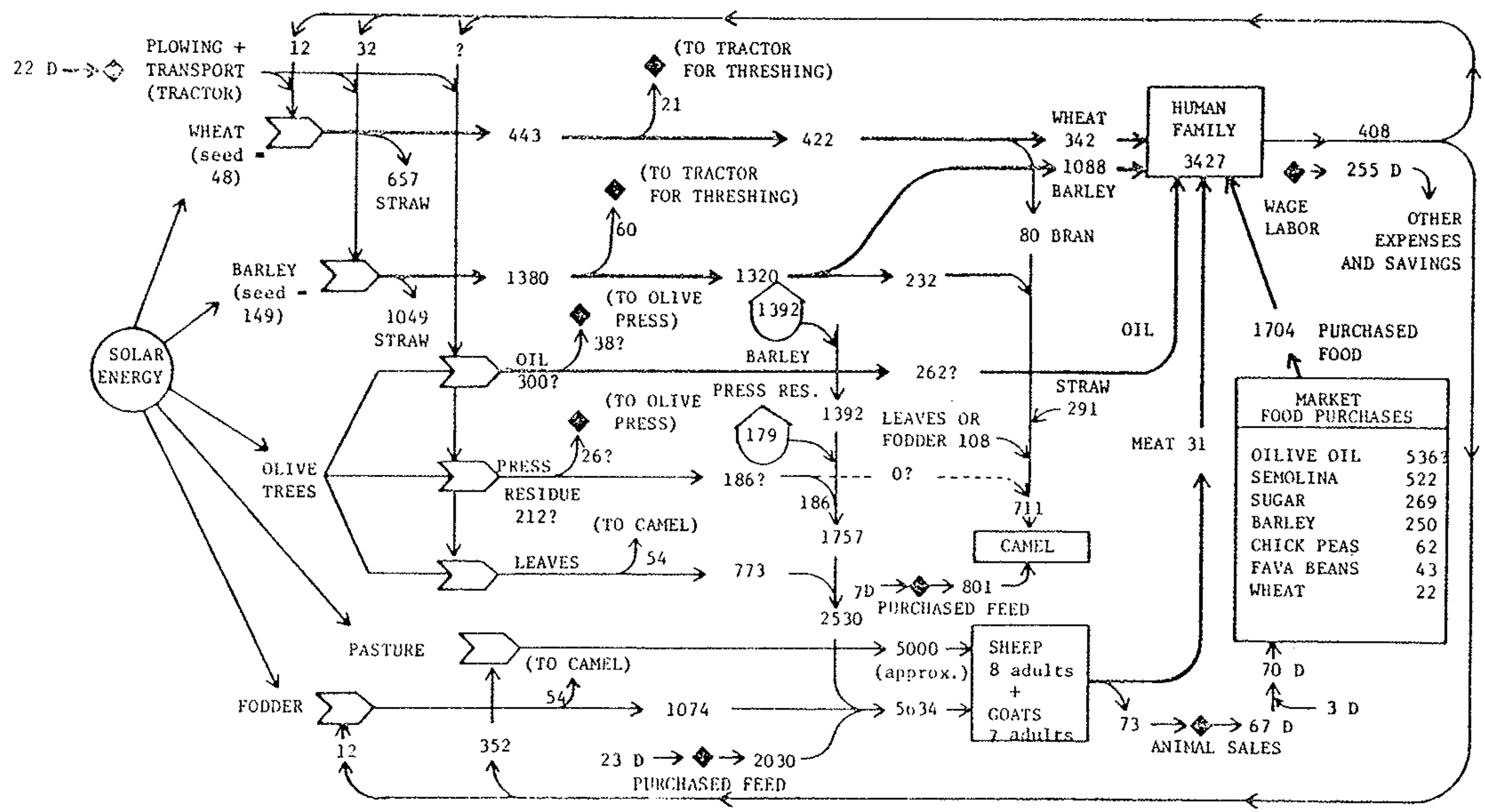


Figure 18.5. Energy flow (during dry 1972-73) through the average human family in the PreSaharan ecosystem.

minimal (2% of all wheat consumed), but this was supplemented by purchases of semolina during the year.

No additional seed was purchased for the barley and wheat planting of 1972. As noted above, family heads are less willing to risk the loss of seed and labor on a poor harvest which can be anticipated during a year of low rainfall.

Another result of the tendency to minimize risks in a bad year is the decreased use of tractors for plowing. Tractor costs for planting grain in 1972-73 were the lowest of any year observed (5.8 dinars). However, more money was spent on tractor transport of the harvest to the home base in 1972-73 than in 1973-74. This increase relfects the greater distance of the planting sites from the home base during a dry year in the study area.

Olive production: Questions on olive production during 1972-73 were deleted from the economic survey in order to incorporate questions concerning a bumper year of olive production (1969-70). Production during this earlier year is not reported here. According to some informants, olive production was minimal on the home base in 1972-73. The estimate for olive production in Fig. .5 has been set lower than the 1974-75 level to reflect informants' statements. It is probable that large purchases of olive oil were necessary to supplement family production.

Fodder harvest: The amount of annual and perennial plants harvested in spring 1973 was quite comparable to the amount collected in 1973-74. This similarity is somewhat surprising, since rainfall was so poor on the home base. This may indicate that in 1972-73, the family collected plants from distant land holdings where rainfall was sufficient to support adequate vegetation growth. The 1 million kcal of harvested fodder was not sufficient to fulfill the food supplement needs of the herd in 1972-73. Two million kcal of purchased feed was also given to the goats and sheep. In addition, 2.5 million kcal of feed from home-produced agricultural products were given to the herd. The total non-grazed portion of the sheep and goat diet amounted to more than 5.6 million kcal or 50% of the estimated caloric need of the herd in 1972-73. The purchased feed component was 20% of the total diet of sheep and goats.

Animal diet supplementation versus herding transhumance: Since the inhabitants of the study area were formerly more nomadic, one might expect that during a dry year on the home base the herds would be moved, as in the past, to an area of better rainfall. This would reduce the need for feed supplementation. However, in 1972-73 only one of the 24 study families moved the herd entirely away from the home base. Three others moved the herd to a different location for only 6 months during the year. Therefore, most of the animals in the study area were on the home base during the dry year.

As indicated above, the amount of dietary supplementation in 1972-73 was considerable. In the past, a dry year on the home base would always have meant a move of the herd and the family to better pastures. At present there are two choices which the family will consider during a dry year. The herd can be maintained on the home base and supplemented with non-grazed animal feed. Alternately, it can be sent with a professional shepherd (or a responsible family member if one is available) to a better pasture area.

Most of the families in the study area chose to keep the animals on the home base during 1972-73. This involved a considerable expense in the form of cash expenditures for purchased feed and of large quantities of home-grown feed. The amount of money spent by the sample families on purchased feed in 1972-73 for the sheep and goats was 22.7 dinars. If these same families had instead chosen to send their animals with a shepherd for even 6 months, the cost would have been a least 40 dinars. This cost is based on the standard herding service fee of .4 dinar per adult animal per month. The cost of sending the animals away from the home base during a poor year is therefore substantially more than the cost of leaving the animals to graze on the home base in combination with a dietary supplementation program.

Cash income and expenses: The method of estimating cash income from animal sales in 1972-73 is the same described previously. There were on the average, 15.6 adult females reported in the herds for 1972-73. The estimated cash income from sales of animals was 67 dinars. In addition to this, 255 dinars were earned from wage labor. A total cash income of 322 dinars was available to the family during the year.

The routine family expenses during 1972-73 amounted to 79 dinars. However, this figure cannot be compared to the expenses of other years because data are lacking for production and expenses related to the olive harvest. However, a rough estimate for these expenses is 42 dinars, based on corresponding data for the other years studied. Adding this to the actual documented expenses, the total was 121.6 dinars.

This estimate is larger than the amount for any other year studied, and reflects the generally poor quality of the agricultural cycle and the resulting large expenses of food purchases for family and herd. The total cash income reported above is the lowest of any of the years studied. Therefore the net surplus cash available for savings is lower in 1972-73 than at any other time for which data are available.

Dependence on the ecosystem for population support-- The information on annual energy flow can be averaged over the 3 years for which data are available. This procedure should provide an approximate indication of average economic conditions during the recent past. The result can then be evaluated to determine whether the population can meet its needs from food produced and cash earned exclusively from within the ecosystem. Fig.18.6 will help to clarify how a population which needs cash for the purchase of services, goods, and foods not obtainable in the ecosystem can, in spite of this, be thought of as being independent of sources of income from outside of the ecosystem.

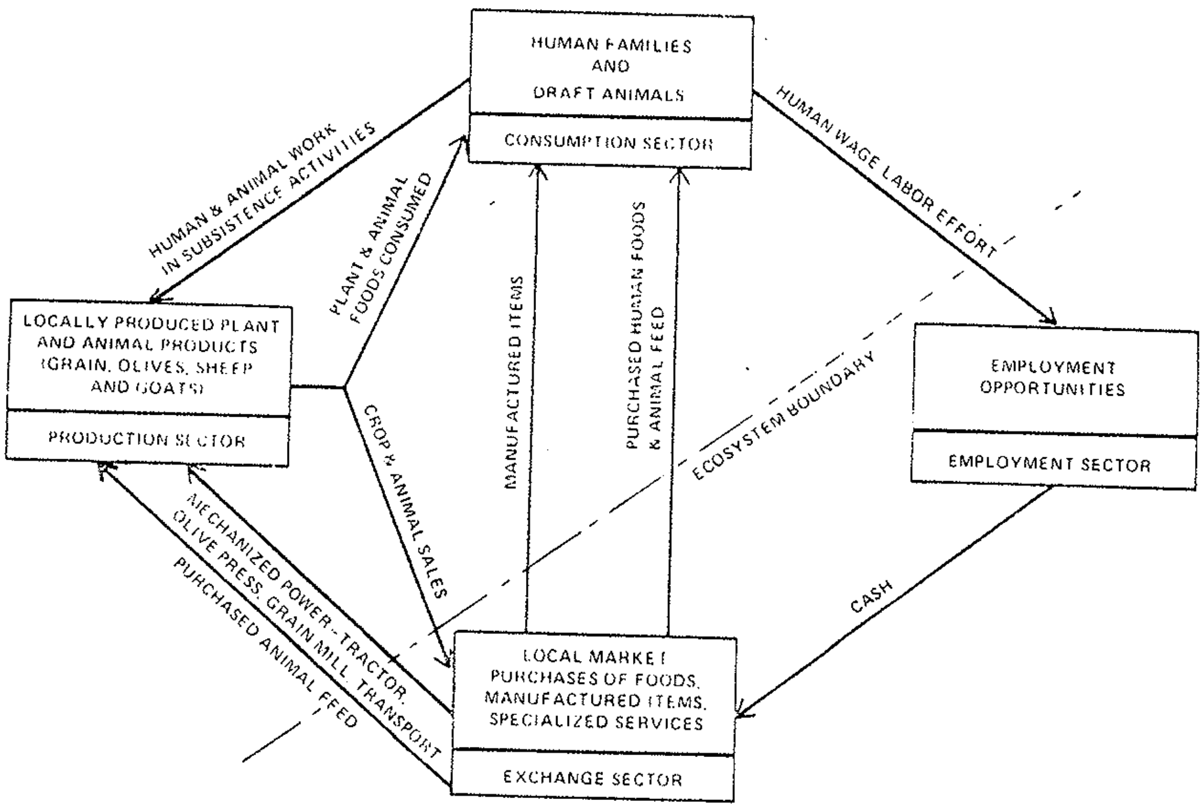


Figure 18.6. Simplified energy flow system integrating with a cash economy.

Fig. 18.6 is a much simplified representation of the average energy flow through the human population in southern Tunisia. If family needs are to be completely satisfied by the proceeds of economic activities performed within the system, then two conditions must be met:

(1) The dietary needs which cannot be met directly from the production sector must be met by the sale or exchange of local products in order to obtain food items produced in other ecosystems.

(2) There must be sufficient cash from the sale of unconsumed local products to enable the family to purchase outside services and manufactured goods. This situation could be represented by modifying Fig. 18.6 so that there were no links to the employment sector. Wage labor opportunties would simply be ignored by rural families since they would earn enough income from the sale of locally produced goods to purchase all the specialized goods and services they need.

By averaging the data on energy flow for the 3-year period (Fig. 18.3, 18.4, and 18.5), one can determine if the two conditions mentioned above can be met. If they can, then production is sufficient to meet the requirements of consumption and exchange of local products by the population. There are some conceptual problems in analyzing the average energy-flow conditions based on the 3 years for which data are available. The order in which the wet and dry years occurred in the study period is important in terms of how one views overall energy balance for the 3 years. In this 3-year period a poor year preceded a nearly average year, which was followed by a very abundant year. During the poor year there was a heavy emphasis on purchasing food for human and animal consumption. During the near-average year there was still a large amount of purchased food in the human diet. During the abundant year an excellent grain crop was produced, enabling the family to put a large amount of grain into storage for anticipated periods of shortage in the future. When these 3 years are averaged (Fig. 18.7) a peculiar result is obtained. From Fig. 18.7 it can be seen that an average net wheat production of 1.121 million kcal were obtained over the 3-year period. This amount is slightly higher than the 1.088 million kcal of wheat needed by the family each year. One might assume at first glance that the south Tunisians produce enough wheat on the average to meet their dietary needs. However, if the next step in the flow chart is considered, one finds that an average of 371 thousand kcal of wheat are put into storage each year. Considering that nearly all the average wheat production (1.088 of 1.121 units) should be used in the human diet, such storage does not make sense. In addition it can be seen that an average of 268 thousand kcal of semolina (a substitute for whole-grain wheat in the diet) was purchased. This also seems inappropriate since the extra purchase should not have been necessary if the family had enough wheat to meet its average needs.

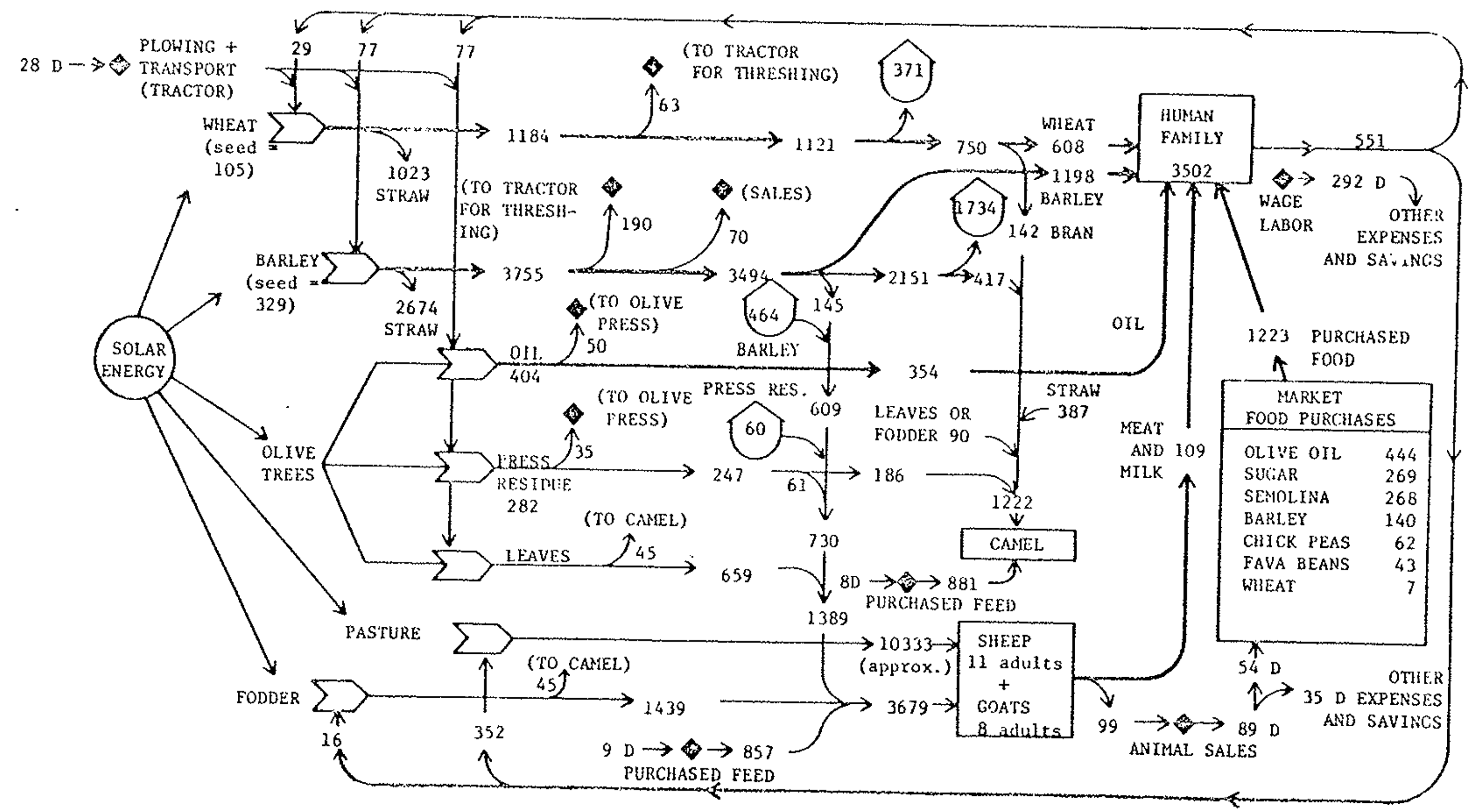


Figure 18.7. Energy flow (three year average) through the average human family in the PreSaharan ecosystem.

The peculiarity can be explained by recalling the 3-year production sequence. Abundant overproduction occurred in the last of the 3 years and could not possibly have been used 2 years earlier during the year of wheat shortage. If the abundant year had been the first year in the series, then the surplus could have been used later during the poor year. In that case, no extensive purchases of grain products would have been observed.

How, then, should the average energy flow of agricultural products be evaluated? One method is illustrated for wheat and for barley in Table 18.1 Since different patterns occurred in each of the years studied, the average energy-flow situation represented in Fig. 18.7 will include an average amount of grain put into storage, an average amount of grain taken out of storage for consumption, and an average amount of grain purchased to supplement family and herd needs. All three components will occur in the "average" year reprsented in Fig.18 .7. In evaluating net energy balance under these conditions, grain produced locally is assigned a positive value, while grain consumed locally is assigned a negative value. Any grain or grain product imported into the ecosystem (e.g. purchased in the market) is also assigned a negative value. The method used in Table 18.1 is to calculate the average amount of home-grown grain which is stored (average local production minus average human and herd consumption of home-grown product). From this amount one subtracts the average amount of grain taken from storage (if any) and the average amount of purchased grain (or its equivalent). This manipulation is done in terms of kilocalories. The remaining amount of food energy should represent the average net accumulation or deficit in grain during the 3-year study period. In this way the effects of the order in which wet and dry years occur are eliminated.

From Table 18.1 it is evident that for wheat there is a slight deficit in net annual energy balance. However, this deficit is rather small. It only amount to 6.6% of the annual need for wheat for human food and for seed. The errors involved in the estimates in Table 18.1 probably amount to more than 6%. Therefore it is inappropriate to accept this small deficit as a proven fact. The safest conclusion is that the population is very nearly in energy balance for wheat over the 3-year study period.

Calculating the net energy balance for barley involves some additional problems. There are several consumers in the family economy which eat barley and which have not been considered in the energy-flow model. These are the family's donkey or mule, chickens, and dog. Quite clearly the combined nutritional needs of all these animals is far less than the nutritional needs of the human and animal consumers which have been considered in the model. Thus the majority of energy consumed by humans and domestic animals has been accounted for. However, the small amount of unaccounted energy is important because of the size of the apparent net energy surplus for barley reported in Table 18.1. It is not a large surplus and could be substantially diminished if an estimate were available for the average annual barley needs of these minor consumers. Research efforts are presently being directed toward estimating barley consumption of these consumers. The safest conclusion based on present knowledge is that the population is probably self sufficient in barley production but that there may not be any net accumulation of barley in this system.

The validity of the Table 18.1 estimate of annual energy balance is based on two assumptions. The first is that the average rainfall during the 3-year study period (98mm) was representative of the long-term average in the PreSaharan area (100mm). This appears to be a valid assumption. Therefore the amount of grain produced can be considered to be a realistic average for the PreSaharan ecosystem, since grain production is a function of rainfall.

The second important assumption on which Table 18.1 is based is the constancy of the food consumption rate (kcal/year) of the various consumers in the family and its herd. Is this consumption rate (based on a 3-year average) representative of the long-term conditions for families in this ecosystem? Family consumption during a given year must equal caloric requirements which are determined by demographic composition and body biomass of the family and the herd. The average herd size increased during the 3-year study period. This increase may have been a maximizing strategy to increase lamb and kid sales by decreasing older adult female sales and increasing young adult female purchases during years of progressively better rainfall. The extra investment in purchased females would have been considered safe during 1974-75 because of the expected high level of vegetation production for that year.

During the poor year, selling strategies could not be observed. If the 3-year study period had been more arid, perhaps adult female animals would have been sold, and fertility of females would have been lower. Increased sales and decreased fertility would have diminished the natural rate of increase of the herd. On the basis of available data no conclusion can be reached concerning the stability or growth of herd size. It is not known whether the 3-year increase in herd size will continue over the long term in southern Tunisia.

For the human consumers, no data are available on changing family size or composition. Based on present data for the human non-human consumers, it is impossible to assess the vailidity of the assumption that the family economy during the 3-year study period shows a rate of energy consumption which will remain the same over the long term. Perhaps a reasonable way to deal with the uncertainties involved with Table 18.1 is to conclude simply that during the study period, the family seems to have been able to produce enough grain to meet the needs of all the consumers associated with it. On the basis of Fig. 18.6, the production sector of the energy-flow system can support the consumption sector in terms of the need for grain.

This balance of local production and consumption is not true for olive oil. An average of 404 thousand kcal are produced each year (Fig.18.7). Reported family cosumption of olive oil is 798 thousand kcal per year. Therefore a large amount of oil was purchased each year from sources outside the ecosystem, suggesting an annual energy deficit for olive production.

The next step in assessing the overall productivity of the ecosystem is to determine if there is a sufficient amount of unconsumed local products which can be converted to cash to enable the family to

Table 18.1

Annual Net Energy Balance for Grain in the PreSaharan Subsistence System

	1,000 kcal[1]	Activity
		Wheat
	+ 1121	home production
	- 750	consumption of home-grown wheat
=	+ 371	annual surplus put into storage
	+ 371	
	- 7	purchased wheat
	- 268	purchased semolina
	- 70	bran--loss from conversion of annual surplus into usable human food
	- 105	seed for subsequent planting
=	- 79	ANNUAL NET ENERGY BALANCE
		Barley
	+ 3494	home production
	- 1198	human consumption of home-grown barley
	- 145	home-grown barley to goats and sheep
	- 417	home-grown barley to camel
	- ?	consumption by donkey or mule, chickens, dog
=	+ 1734	annual surplus put into storage
	+ 1734	
	+ 70	sale of home-grown barley
	- 150	purchased barley for camel
	- 171	purchased barley for goats and sheep
	- 140	purchased barley for family
	- 464	barley taken from stored reserves of home-grown product for goats and sheep
	- 329	seed for subsequent planting
=	+ 550	ANNUAL NET ENERGY BALANCE

[1] Based on Fig. 18.7

purchase needed food, manufactured goods, and services. By far the most important of these local products are sheep and goats sold from the herd. Certain categories of animals are sold in the local market , thereby converting ecosystem production into cash via the exchange sector. The average cash income from the sale of these animals is 89 dinars each year. It must be spent via the exchange sector to provide foods and manufactured items for the consumption sector. The cash must also be used to provide mechanized power services and purchased animal feed to support the production sector. The average cash needs of the consumption and production sectors are 103 dinars each year. This is based on accountable expenses during the 2-year study period. This amount is probably an underestimate of average annual cash expenditure. Quite evidently the 89 dinars derived from unconsumed food resources in the production sector cannot pay for all the cash needs of the family (103 dinars or more).

Apparently this population cannot produce enough cash-earning products to support its need for money since it cannot produce enough olive products to meet its dietary needs. Therefore neither condition 1 nor 2 as specified above are met by economic production in this ecosystem. As a result, the human population is dependent upon outside sources of income to meet its dietary and cash needs. Thus Fig.18 .6, (which includes the link to the employment sector) represents the flow of energy in the study population.

Participation in wage labor by individuals from this population is explained as a result of the demonstrated need for sources of income from outside the ecosystem. An average of 292.6 dinars was earned from wage labor each year by sample families. This labor was performed in industrialized areas outside the PreSaharan ecosystem. The estimated 103 dinars of average annual expenditures has been previously shown to be an underestimate of family expesnes. This partly explains why the total income (292.6 dinars from wages and 89 dinars from animal sales) is so much greater than the estimated cash needs of the family. Another possible explanation is that the families are attempting to earn a cash surplus to develop a large family treasury. Several possible motivations for this have already been discussed.

Annual Differences in Soil Disturbance from Human Economic Activity

Part of the purpose of the research in southern Tunisia has been to determine the human contribution to the processes of soil and vegetation deterioration called desertization. Just as economic production varies with the amount of annual rainfall, so does the amount of land put into cultivation. The specific method of cultivation used to make the land productive also varies with the amount of annual rainfall. Specific grain harvesting methods depend on the quality of the harvest and these also differentially influence soil disturbance.

Olive production-- The most important characteristic of the olive tree as a productive resource is that it is the only stationary resource in the south Tunisian economic system. Each year the olive orchards must be cultivated at least twice, regardless of the amount of rainfall. There is no other roductive resource for which repeated cultivation is necessary.

The effect of periodic plowing can be seen in Fig. 18.8. In the foreground a mobile sand dune can be seen indicating that loose sand is accumulating down wind from the olive orchard. The only aspect of olive cultivation which appears to change each year in response to the amount of rainfall is the relative balance between plowing by tractor and dry draft animal. With the tractor, the depth of penetration of the plow into the soil is deeper which causes more soil disturbance. Data on the amount of tractor plowing of olive orchards is shown in Table 18.2. In a year of excellent rainfall there is more emphasis on tractor plowing than is the case in a more average year. However, even in an excellent year, less than 50% of the orchard land was plowed with a tractor.

Grain cultivation-- Many of the major aspects of grain cultivation and production can be seen to vary with annual rainfall (Table 18.2). The area of land put into grain cultivation increases sharply from the poorest to the best year. This is accomplished with the aid of the tractor. The apparent strategy is to plant as much grain as possible in a good year and to cut back sharply on the area planted during a dry year. This is an effective method of maximizing grain production in a good year and minimizing the potential loss of invested resources in a bad year. The result of the observed planting strategy is that the increase in harvest size in a good year is proportionately greater than the increase in area planted or than the increase in effort, money, and seed invested.

An illustration that the above is an expectation of the family is the willingness to invest large amounts of money in tractor plowing services during a year of above-average rainfall. The same trend is seen for grain cultivation as for olive cultivation. Namely, during an abundant year there is more emphasis on tractor cultivation than during an average year. During the abundant year (1974-75) tractors plowed 66% of the land put into grain production. The proportion of tractor plowing during the other years is close to 50%.

An important variable mentioned earlier, which is also determined by annual rainfall on the home base, is the distance of the grain planting sites from the home base. In a wet year a large portion of the grain planted by the family will be concentrated on the home base. Some grain is also planted on distant sites, however, in order to maximize the anticipated harvest size. On the other hand, in years of lower rainfall on the home base, the family must plant all or nearly all its grain at more distant sites. In those years the only tractor cultivation on the home base is the minimal amount of olive orchards. The concentration of tractor plowing on the home base during a wet year is a practice which is likely to increase desertization.

Techniques for harvesting grain also vary. If the wheat harvest is good and the plants dense, they are cut with a sickle. This leaves a stubble which is grazed by the sheep and goats, leaving the roots in the ground to help stablize the soil surface and decrease wind erosion (Fig. _ .9). If the wheat harvest is sparse due to poor rainfall, the entire plant is pulled with the roots. For barley, regardless of the quality of the harvest, the entire plant is usually pulled. Since barley covers the major part of the land cultivated in grain (70%), its characteristic harvesting technique is the dominant factor determining the contribution of grain cultivation to soil disturbance. Most of the

Figure 18.1. The damage of frequent plowing is shown in this olive orchard which is well weeded by plowing two or more times each year. Note the small, active sand dune in the foreground indicated by the characteristic ripples in the bare sand. Photograph by William H. Bedoian.

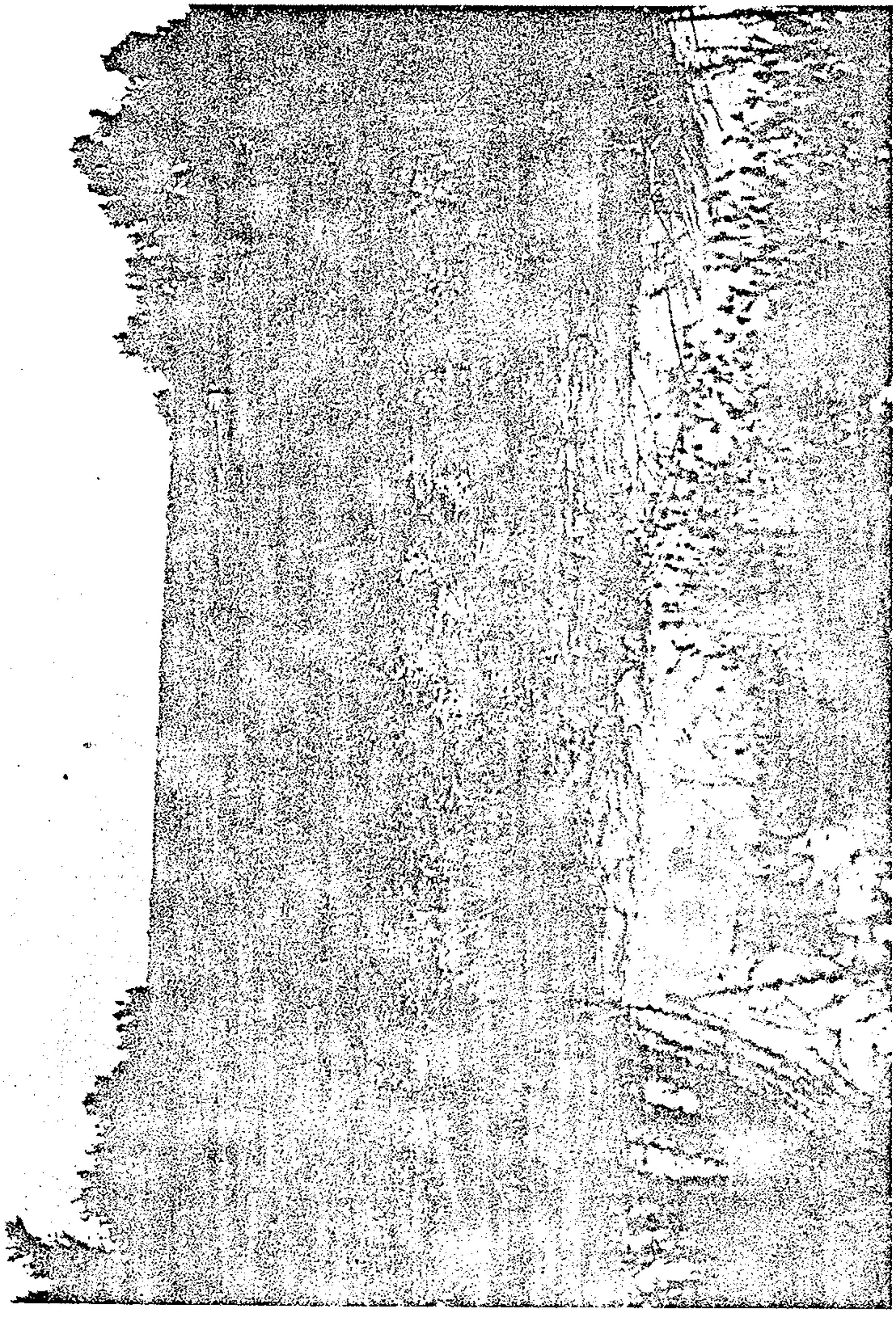


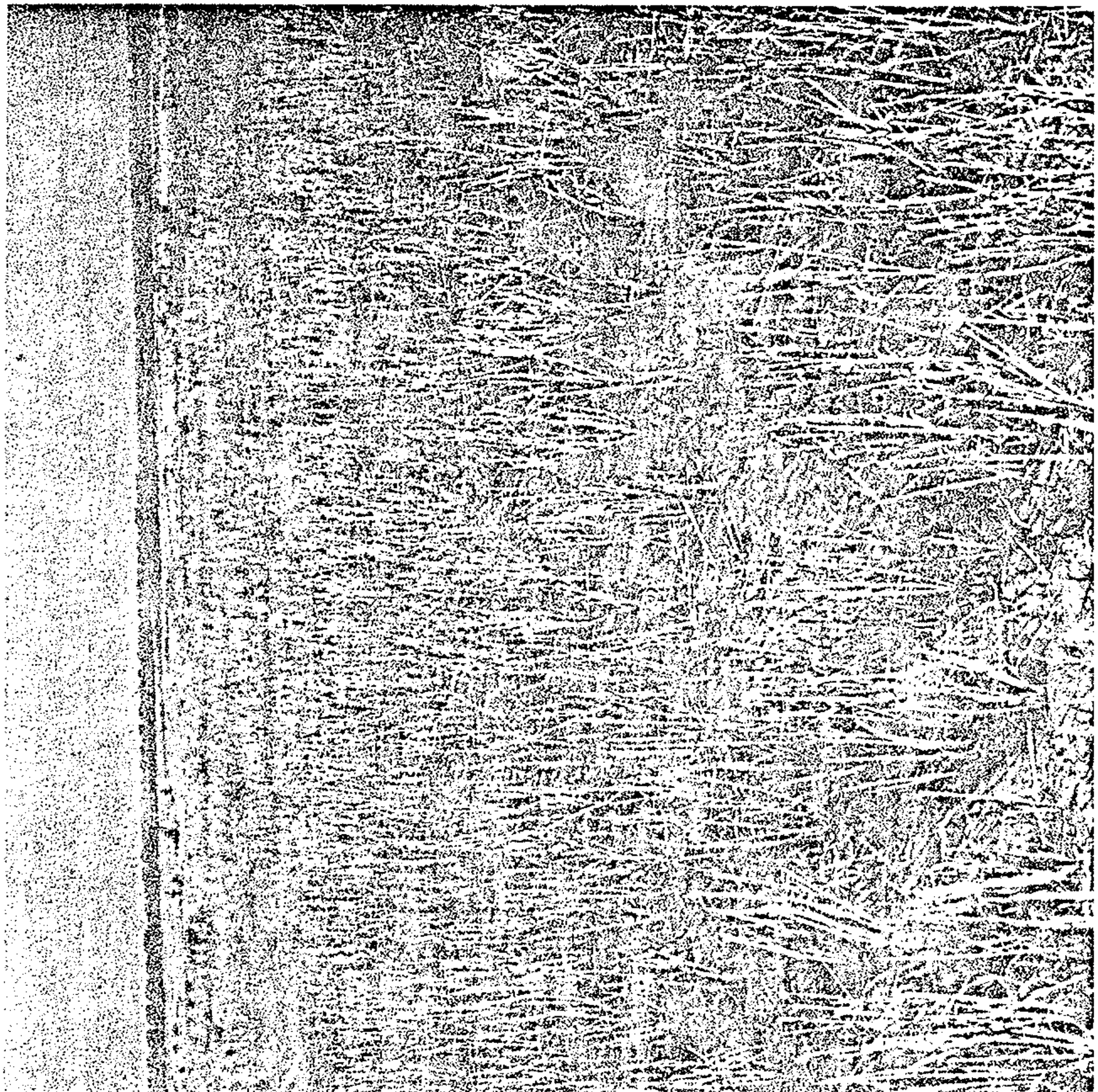
Table 18.2

Variations in Hand-use Patterns (Sample Averages) as a Function of Annual Rainfall During Three Agriculture Cycles

Activity	Area Expenditure or Yield by Annual Rainfall[1]		
	15 mm (1972-73)	94 mm (1973-74)	186 mm (1974-75)
Olive Cultivation			
Olive orchard area plowed by tractor		1.5 ha	2.1 ha
Olive orchard area plowed with draft animal		4.1 ha	3.6 ha
Grain Cultivation			
Total area planted in grain	3.7 ha	8.5 ha	12.5 ha
Total grain area plowed by tractor	2.0 ha	4.0 ha	8.2 ha
Total grain area plowed with draft animal	1.7 ha	4.5 ha	4.3 ha
Money spent on tractor for grain planting	5.8 d	8.0 d	16.4 d
Wheat yields	122 kg/ha	94 kg/ha	197 kg/ha
Barley yields	158 kg/ha	114 kg/ha	253 kg/ha

[1] Measured on Tunisian PreSaharan project study site (average of 5 rain gauges).

Figure 18.9. The use of a sickle to harvest the wheat results in the lower stalks of the wheat plants remaining in the ground. This stubble is then grazed off by goats and sheep until only the root systems remain. Photograph by William N. Bedoian.



time, barley patches are left completely denuded after the harvest (Fig. 18.10).

Impact of land-use types on desertization-- In order to assess the major land-use types (grazing, olive culture, grain culture) as factors contributing to desertization, two variables must be considered. One is the amount of land area subjected to a given land-use type, and the other is the amount of soil disturbance per unit area. In terms of the amount of area used, grazing has the greatest impact on soil disturbance. Based on sample averages, 54 hectares are grazed on the home base each year by the family herd. Only 7 hectares are cultivated in olives, and an average of 8 hectares are cultivated in grain (averaging wet and dry years together). In terms of overall surface area alone, one would conclude that grazing is the most important contributor to vegetation desctuction, soil movement, and desertization.

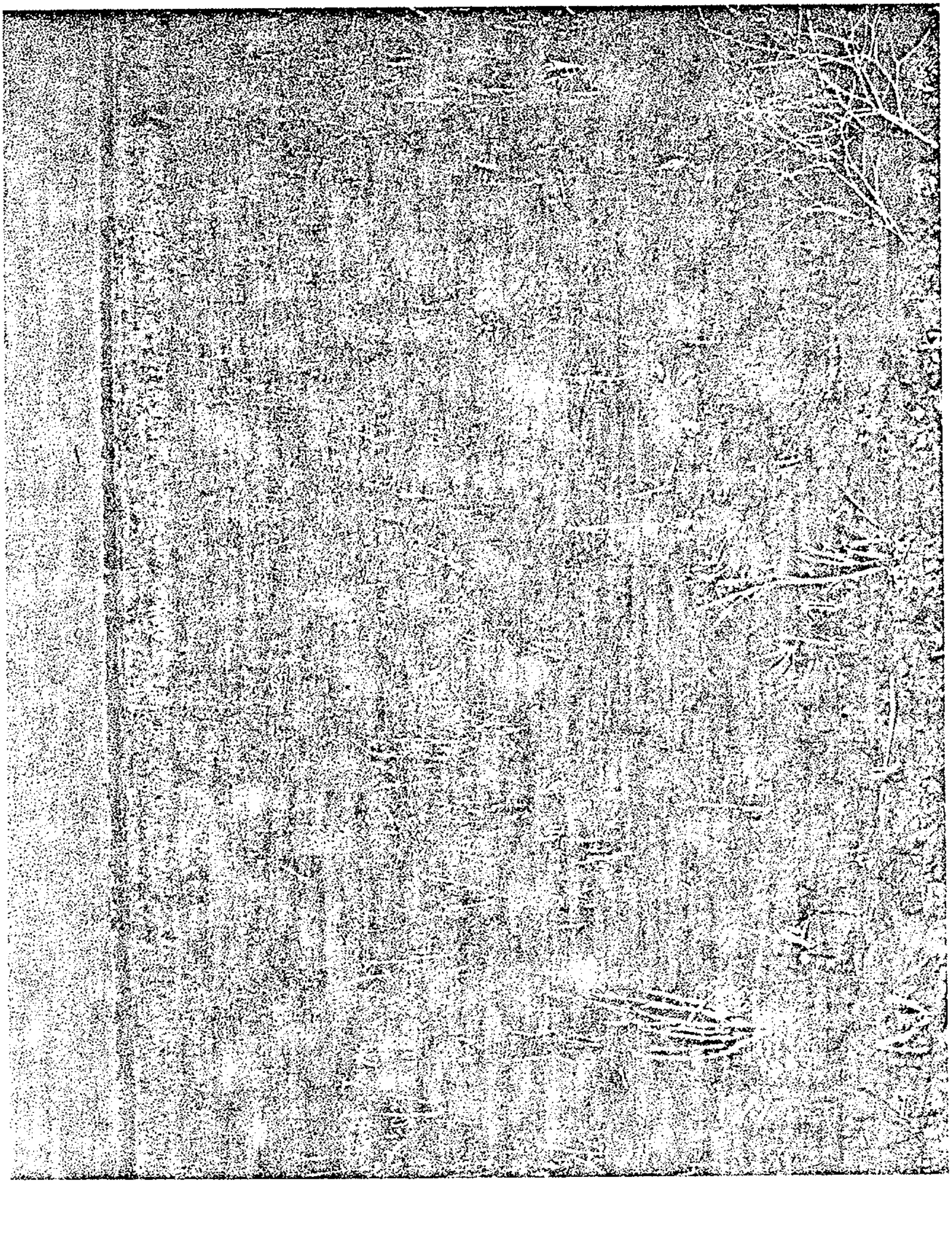
The impact of sheep and goat grazing can be seen in Fig.18 .11 and 18.12. In Fig.18 .11, the study site of the Tunisian PreSaharan project is shown in an oblique view from the air. The enclosed borders of the study site are clearly visible due to the contrast between the thick vegetation cover within the site compared to that found on the locally grazed land surrounding the site. The vegetation improvement has occurred within 3 years on the study site even though the vegetation is exposed to a controlled grazing regime. Fig.18 .12 is a vertical view of a human habitation (large arrow) near the PreSaharan project study site. A part of the study site appears as a darker area in the corner of the photo. The animal corral (circled) is surrounded by a light area (arrows) which is completely lacking in vegetation cover. This results from the constant trampling of the vegetation by the animals milling around the corral site. Mobile sand dunes accumulate in a semicircle (dashed line) down wind from the corral.

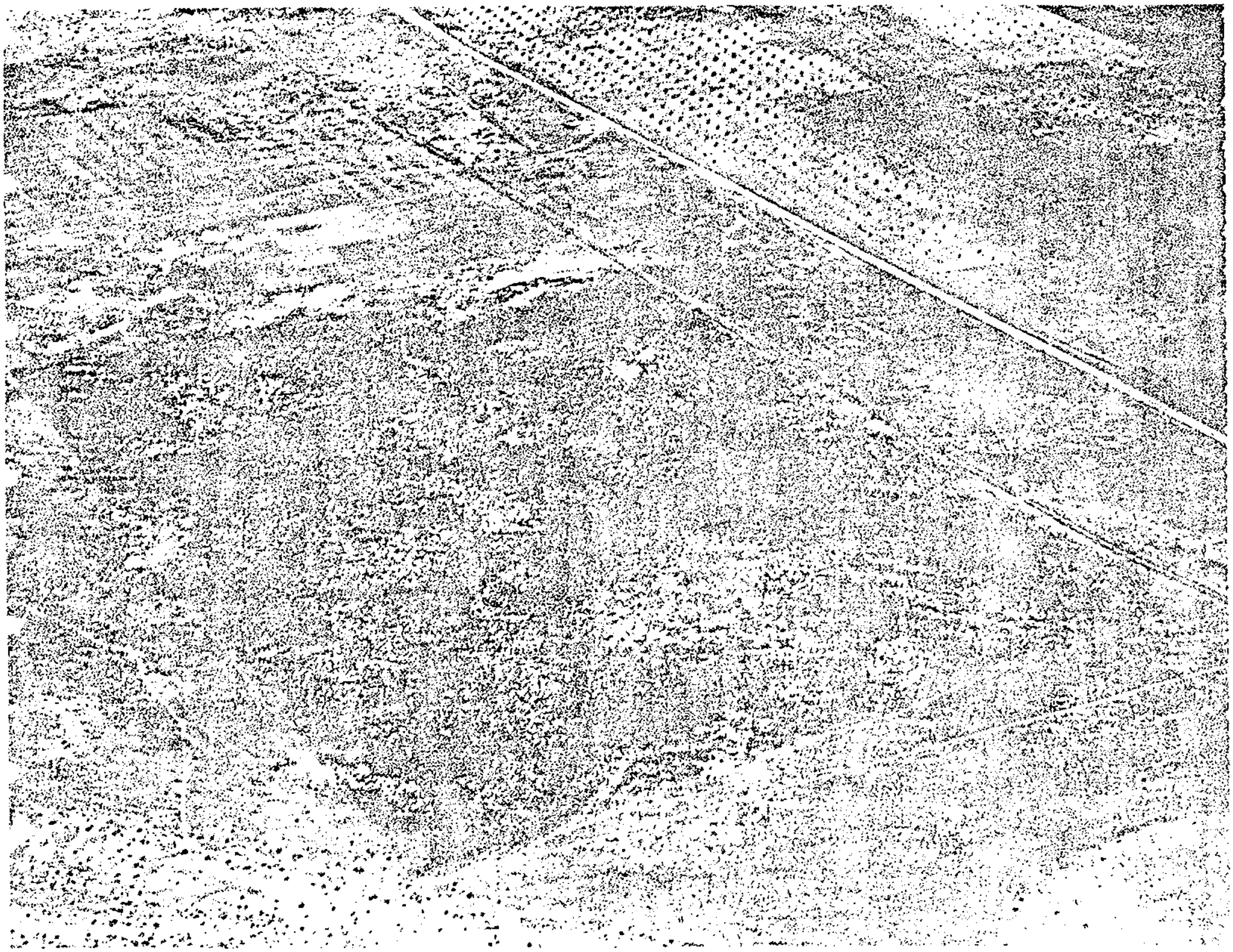
In terms of the amount of soil disturbance per unit area grazing is not the most important contributor to vegetation destruction. Obviously plowing creates more disturbance per unit area than does grazing. As mentioned above, olive cultivation is always performed several times per year on a given piece of land. This does not happen with grain cultivation.

In terms of the frequency and degree of soil disturbance per unit area, one can rank various land-use types in terms of their contribution to desertization. Olive cultivation would rank highest as the most destructive because of frequent plowing. Home-base grain cultivation would be intermediate, and distant-land grain cultivation would be the least destructive since plowing is not frequent on a given site. In this ranking, grazing would be the least destructive of the land-use types per unit of area disturbed.

Combining the two land-use characteristics (per unit soil disturbance, and number of hectares disturbed) one can get an idea of the overall importance of each land-use type as a contributor to desertization. Grazing covers 78% of the land used by the family and plowed land amounts to 22% of such land. The least destructive land-use type (grazing) covers

Figure 18.10. A recently harvested barley field shows that virtually no vegetative cover is left after a harvest. The entire barley plant, including the roots, is pulled up by hand without the use of a sickle. About four-fifths of the grain planted in the Dar ez Zaoui locale is barley. Photograph by William H. Bedoian.





Frontispiece. Oblique aerial photograph of the 50 hectare Dar ez Zaoui site showing the improvement in vegetation condition after only three growing seasons under the project land management. Details of soil and vegetation changes are discussed in Chapters 14 and 15. Photograph was taken in the spring of 1975 by William H. Bedoian.

Figure 18.11. From an oblique aerial view the Dar ez Zaoui research site stands out as a clear defined, dark rectangle of vegetative cover against the more poorly covered surrounding area of native grazing land. Within the site there seems to be no difference between the grazed area and the ungrazed area in terms of the visual aspects of vegetative cover. Photograph by William H. Bedoian.

Figure 18.12. A microcosm of desertification can be seen in this vertical aerial view of a human habitation site north of the Dar ez Zaoui research site. The animal corral (circled in the center of the photo) is surrounded by a light colored area (indicated by the four arrows below the circle) showing where the vegetation has been completely removed from the land by sheep and goats which congregate in and around the corral during non-grazing periods. The dark blotches on either side of the corral are former corral sites where the dung buildup has stained the sand a darker shade as seen from the air. The human family inhabits the paired huts shown by the single arrow above the circle. In the upper left corner the boundary of the controlled grazing plot is clearly visible. In the extreme lower right corner is a gully in which sand dunes are being deposited by wind erosion. In a semicircle downwind from the present corral, sand is also accumulating in small dunes (area indicated by dashed line). Photograph by William H. Bedoian.

the largest portion of exploited land, and the most destructive land-use type (plowing) covers the smaller portion of exploited land. In this sense, grazing and plowing may make somewhat comparable contributions to the processes of desertization.

Land-Use Strategies in Southern Tunisia

It has been shown that energy flow in the human population in southern Tunisia is at a level which is slightly below the minimal level necessary to support the human and domestic animal population. This is probably a recent development resulting from decreased land availability due to a steadily growing human population. In the past, more land was available to each family, herd sizes were larger, and animal sales provided a larger cash income. In the past the population was probably independent of income sources originating outside of the ecosystem. Under those conditions, energy flow may have been a limiting factor on the human population. One would expect to see population responses which maximized energy production or minimized energy expenditure. These patterned behavioral and/or biological responses may have remained in the present system. If they have, one would expect that food production would yield a high energy return on the investment of human labor.

Efficiency of agricultural production -- The efficiency of subsistence production can be evaluated in terms of the amount of human effort required to produce the crops and animals which serve the food requirements of the population. An effective or efficient method of subsistence production is one which minimizes energy expenditure in work effort and maximizes energy production in crops. This efficiency is always viewed within the context of the constraints of the ecosystem. Given a set of possible subsistence alternatives, it is expected that individuals will choose those methods and crops which result in the highest long-term energetic efficiency (food energy produced/work energy expenditure).

Compared to other low-productivity ecosystems the energetic efficiencies of southern Tunisian subsistence crops seem to be fairly high. They are as follows:

(1) Barley grain, 46.3 : 1
(2) Wheat grain, 38.6 : 1
(3) Olive oil, 7.7 : 1

Using barley as an example, the meaning of this ratio is that 46.3 kcal of grain are produced for every kilocalorie spent as human work necessary to produce the crop. These estimates are rather approximate for several reasons. First, animal food such as chaff, bran, straw, olive leaves, or olive-press residue has not been considered in the production factor. Second, the amount of draft animal effort is excluded from the expenditure factor. Third, the money earned in animal sales has a caloric work cost and, since some money is spent in crop production, the portion of this money resulting from animal sales has a caloric cost.

This cost should be considered in the expenditure factor of the efficiency ratio. Data are currently being analyzed so that these items can be included in the efficiency ratio of the southern Tunisian crops.

The estimates show that the grain-producing system is well adjusted to the constraints of the ecosystem. Olive oil production is not an efficient process compared to grain production. However, this ratio does not take into account the production of animal food from olive by-products. The efficiency ratio would be closer to 15 : 1 if all materials were considered in the production factor. This complex of efficiently produced crops is what one would expect if energy flow was formerly a limiting factor for this population.

Conversion of surplus animal production into alternate foods -- One of the main subsistence strategies of the PreSaharan population is to convert animal production into cash to purchase foods and goods and services which are not locally available. The conversion of live-animal energy to cash to purchased food energy involves an energy return which is a useful way of evaluating this pathway of energy transformation. Table 18.3 provides the various rates of the conversion of live animal energy into purchased food energy via the market system. The indicated amount of meat energy will bring 1 dinar at the market (live animal sales). In turn, 1 dinar will buy the specified amount of any of the indicated food alternatives.

The conversion of live animal energy into human food energy via the market system brings a considerable caloric return to the family. A return ranging from 15 to 50 kcal of human food energy is received for every kilocalorie of live meat sold. In terms of subsistence strategies it can be said that the animal herd acts as a bank of energy reserves of which a small part is converted into human food every year. Considering the kinds and average amounts of foods purchased (based on Fig. 18.7) there is a 25 : 1 overall return of human food energy purchased for every kilocalorie of animal-meat energy sold.

The conversion of animals into purchased animal feed is also included in Table 18.3 for comparative purposes. There is a higher energy return if animal food is purchased rather than human food. A return ranging from 58 to 175 kcal of animal food energy can be purchased for every kilocalorie of live meat sold. In monetary terms it is less costly to purchase animal food than human food. Based on actual feed purchase patterns, there is an 87 : 1 overall return of animal-feed energy bought for every kilocalorie of animal-meat energy sold.

Economic aspects of food production versus food purchase: Since the energy conversion is so high from live animals sold to food purchased, one might wonder if there is any energetic or economic advantage at all for home-produced food compared to purchased food. It has already been shown that the energetic returns on home-produced food are high. There is also an economic advantage to the home production of food compared to the purchase of food. Home production yields more energy per dinar spent than would be the case for outright purchase of food. This is

Table 18.3

Conversion of Goat and Sheep Production into Other Food Items Via the Market System[1]

Conversion of Animals into Alternative Human Foods

	57,500 kcal barley[2]
	41,000 kcal flour
	38,400 kcal wheat, semolina
1094 kcal meat = 1.0 Tunisian Dinar =	29,400 kcal pasta or sugar
	21,000 kcal chick peas
	20,000 kcal fava beans
	16,600 kcal olive oil

AVERAGE: 1094 kcal = 1.0 Dinar = 27,529 kcal purchased food

Average Energy Return from Animal Sales: 25:1

Conversion of Animals into Alternative Animal Foods

	192,000 kcal olive leaves
	190,000 kcal press residue
1094 kcal meat = 1.0 Tunisian Dinar =	100,000 kcal hay
	93,000 kcal bran
	64,000 kcal barley[2]

AVERAGE: 1094 kcal = 1.0 Dinar = 96,000 kcal purchased feed

Average Energy Return from Animal Sales: 87:1

[1] Values based on market conditions in 1974-75

[2] The price of barley for animal food differs from the price of barley for human food.

because a family which produces its own crops only spends its available cash on incidental agricultural costs such as payment for tractor services or purchase of seed for planting.

In Table 18.4 the total energy value of the average crop harvest has been divided by the total cash expenditure for incidental agricultural costs for the production of that crop. In effect, the crop is "bought" with a certain amount of cash expenditure and a certain amount of family's labor expenditure. The resulting values in energy produced per unit of money spent are presented in Table 18.4. Labor energy has not been deducted from the energy value of the crop.

A comparison with the values in Table 18.3 shows that much more energy is obtained for each dinar spent in home production than is the case for market expenditures on food. If the energy returns on cash inputs alone are considered, the family can obtain five times more gain per dinar by growing its own, and it can obtain twice as much olive oil per dinar by home production. The obvious result is that a family has the same amount of energy available at a lower monetary cost. The energetic and economic advantages of home production are apparently a sufficient inducement to the continuation of subsistence agriculture.

Table18 .4

Energy Returns from Agriculture per Unit of Money Spent

Product	Energy Return/dinar Invested
Barley	294,459 kcal/dinar
Wheat	212,280 kcal/dinar
Olive Oil	30,456 kcal/dinar

Short term strategies (maximizing output and minimizing risks).--

Land holding and inheritance: Although the sampling zone depicted in Fig.18.2 is rather restricted, the families living within the zone own and use land which is scattered over a 75 km strip running parellel to the coast. This strip also runs parallel to the rainfall isohyets. There is also some indication that the vegetation composition of these sites tends to be somewhat uniform. Thus a rather large but specific ecological microzone is considered appropriate and necessary for exploitation by local families. The sample families own sites scattered throughout the strip in small parcels of less than 5 ha each. Five or more of these small plots may be owned. This scattered pattern may be explained in terms of the striking degree of spatial variability in annual rainfall in the PreSaharan zone.

For instance, the small sampling zone (150 km^2) does not uniformly receive rainfall within its boundaries. During the fall of 1972, no measurable rainfall was recorded by the rain gauges on the PreSaharan project study site. Yet 2 km east of the rain gauges grain planting was attempted in that year. This must have meant that at least 10-15mm of rain fell on the eastern site or the people would not have been convinced that planting was worth the risk. This indicates a sharp difference in rainfall over a short distance.

In addition to the acute spatial variability in amount of rainfall, there is no predictable pattern as to the specific location of rain in a given year. Each part of the PreSaharan zone is equally likely to receive rain. As a result of the unpredictability in amount and location of rainfall, the scattered land holding pattern has a distinct advantage. Such a pattern maximizes the probability that adequate rain will fall on at least one plot of the family's available land in each year. This is the best assurance the family has that it will have access to arable land each year.

The nature of inheritance rules in this population assures that the scatter of land holdings will be maintained between generations. When a family head divides his land, each son gets an equal share of each plot of land. If a family head had five pieces of land scattered throughout the zone, each of his sons would receive five smaller pieces scattered in the same way. The nature of the scatter is maintained. The problem of continually decreasing sizes of each generation's land holdings is partly balanced by temporarily borrowing land or by purchasing land adjacent to the small plot which is owned. Purchase is the most likely solution for lands adjacent to the home base, and borrowing is the expected solution in the case of distant land holdings.

Optimizing stragegies of agricultural production: If the land-holding system fails to dampen the effects of the extreme annual variation in site-specific rainfall, then the amount of cultivation is adjusted to correspond to the expected rainfall. Inhabitants of the PreSaharan zone determine the amount of the first autumn rainfall by measuring the depth to which moisture has soaked into the top layer of sand. There is a lower limit of autumn rainfall below which people will not plant.

In addition to the above there is another means of interpreting autumn rainfall. If the rainfall is of substantial amount and occurs early, this is a clue that the rest of the agricultural cycle will also be moist. This is a predictable characteristic of PreSaharan rainfall. The amount of autumn rain is directly proportional to the rain which will occur during the balance of the growing season. This fact is well recognized by the local inhabitants. They make judgements about the adequacy of autumn rainfall as well as predictions of potential crop yields for the ensuing harvest. Based on these expectations the family adjusts the amount of money, seed, and labor it will invest in crop each year.

During a year which is expected to be very moist, every effort is made to plant grain over as large an area as possible. The investment is high but the risks are considered low. During a year which is expected to be dry, little or no planting occurs. The investment is very small because the risks of crop failure are perceived to be very great. This kind of planning explains the very great range in seed, cash, and labor investment illustrated for the 3-year period in Table 18.2 and in the energy-flow models for each year (Fig.18.3-18.5).

Strategy changes imposed by increased sedentarization.-- During the past 20 years, new water sources have been added along the main highway (Fig.18.2) which serves the PreSaharan zone. This has been accomplished by the construction of a pipeline by the Tunisian government. The pipeline originates in an oasis north of Medenine whose rate of water flow is capable of providing water all along the pipeline route. This new water source has attracted settlement in this part of the region. Families which formerly owned a small parcel of land near this road and water source have decided to make this parcel their permanent home base. Concrete houses have been built and adjacent land has been purchased.

Dependable water sources are very important, especially during the summer when every goat and sheep in the region must receive water every second day. This consumption periodically put such a drain on the previously used, hand-dug wells that seepage of ground water into the well was occassionally surpassed by human and animal consumption of its water. During the summer, people were at times forced to wait several hours for seepage to refill the well to a minimal level which enables water to be taken by bucket. The dependability of the new pipeline water source is one of the main attractions to permanent settlement near it.

This water source and the mobility provided by the road have encouraged permanent settlement in a 5 km strip on either side of the road. There is presently a commitment to sedentary residence which was not evident in previous generations. As recently as 15 years ago a family or part of a family would move to the location most suited to grain production and herdgrazing during each new agricultural cycle. This had the effect of spreading the destructive aspects of land use over a wide area, with longer fallow periods for vegetation recovery between each use at the same site. Presently, individuals occasionally find themselves with productive land (due to good rainfall) at their disposal which is too far from the home base to be exploited effectively. The result is that the home base may be cultivated even though rainfall has been better on a distant parcel of family land. The home base is used more frequently with a resulting decrease in length of the vegetation recovery period. This type of land-use intensification speeds up the processes of desertization.

When the inhabitatnts were more nomadic in their settlement patterns they were more likely to move to distant areas for grain planting. The people are now more reluctant to move draft animals, plows, seed grain, human and animal food, and items of shelter to distant grain planting sites than previously.

To a moderate extent the need for the mobility involved in distant-site grain planting has been eliminated by another new strategy. When people wish to plant grain on a distant site they engage a tractor to carry the seed grain to the locale and to plow the land. This can be easily accomplished in 1 day. Formerly the family would have been obliged to endure a 2-week stay in the distant area. Alternately the family might have chosen to remain at the new location for the whole year if it had access to sufficient grazing land for the herd. At present, because of the availability of tractor services, the family head may depart for a distant area and return home the next day after watching the tractor plow the area of land which would otherwise demand 2 weeks of his time. This eliminates the need to transport the family and the materials necessary to plow a distant site.

Prospects for Developing Land-Use Alternatives

Current land-use practices have a clear and undeniably detrimental effect on vegetation and soil stability. These effects are exacerbated by the recent trend to settle in permanent dwellings on a home-base. The home-base land is used much more than it would be if traditional standards of acceptable levels of rainfall were applied. Recovery periods have shortened so that vegetation regrowth has slowed considerably. Each year more land is planted in olive orchards, with the result that more land is permanently cultivated. The orchard is the most destructive form of land use in terms of vegetation removal and soil disturbance. It is unlikely that these land-use trends can continue very far into the future and still yield a sustained level of agricultural and pastoral production.

Incentives to maintain current practices.-- Although the destructive nature of current land-use practices is regrettable, there are substantial incentives within the economic system to encourage the continuation of these practices. These have been dealt with throughout this discussion and are summarized here:

(1) It is cheaper to produce as much food as possible using current methods of subsistence agriculture. One dinar will produce five times more grain if it is invested in home production than it would if it were spent at the market in outright purchase of grain.

(2) The cash acquired from the sale of young male herd animals is presently greater than the cash spent to maintain the herd. This is true despite the considerable expense of purchased animal feed which must be used during a poor year. Thus there is a net cash income from animal husbandry.

Two additional incentives within the system have not yet been dealt with. These are outlined in some detail.

Market conditions: The retail price of olive oil has nearly doubled in the past few years. This trend is a further inducement to exploit the local system. As the price of purchased olive oil increases, the difference in returns per dinar becomes even more favorable for home production (Table 18.3 compared to Table 18.4). Thus there is an increasingly strong incentive to plant more olives in order to produce more oil. Most of the new planting takes place on the home-base.

Population pressure, herd size and tractor use: One of the most critical incentives within the system is quite complex. It is a result of the following chain of events.

After the first major autumn rain there is a period of approximately 15 days during which grain can be planted. If it is planted after this period there may not be enough remaining soil moisture to support the sprouting and initial establishment of the grain seedlings. During this time period a man and camel can plow 5.6 ha of land in grain (18.75 hours of planting/ha, and 7 hours of plowing/day). This is based on field measurements of working rate.

In order for families to achieve the average annual grain production, 8.23 ha were plowed each year. In Fig. 18.13 the actual amount of plowing is shown for each of the 3 years. In 2 of the 3 years, the total amount of cultivated land exceeded the area which a man and camel could plow (dashed line). Most of the families in the sample own only one draft animal. Therefore the 5.6 ha limit on hand plowing applies to most of them.

Because of this limitation on area plowed by draft animal, the subsequent harvest, based on traditional cultivation methods, would be lower than the annual need for grain. The deficit can be made up in two ways. The grain can be purchased or it can be grown by the family with the aid of the tractor. In southern Tunisia the tractor can plow 12 times faster than a draft animal. The combination of draft animal and tractor plowing enables the family to plow all the necessary land within the 2 week sprouting period while spending only a minimum of cash on tractor services.

Formerly, herds in the PreSaharan zone were larger and tractors were unavailable for grain planting. More land was available to support the larger herds due to the smaller size of the human population in the area. The strategy in the past was to plow by draft animal as much land as possible and to make up the deficit in production by purchasing grain. This was accomplished with the proceeds from animal sales. This income was greater in the past because of the larger herd size than at present. It was therefore possible for the family to put forth the extra cash expenditure of buying grain.

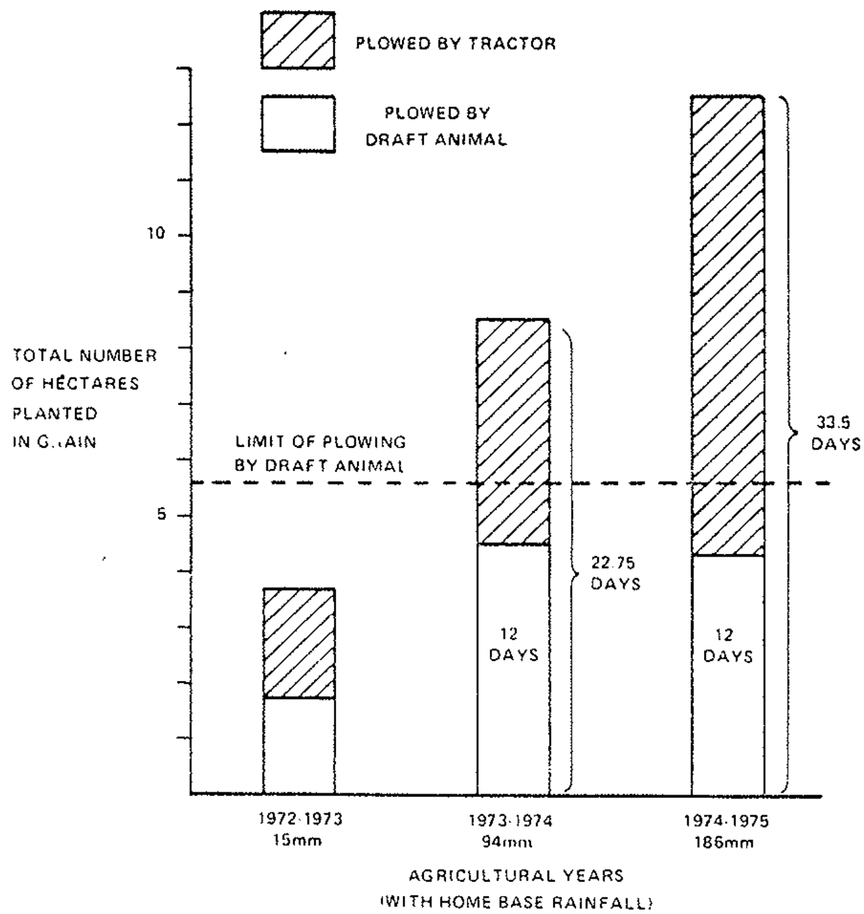


Figure 18.13. Mechanized and traditional plowing patterns during three agricultural cycles.

At present, available land area per family has decreased and herd sizes have been adjusted downward. This has meant diminishing income from animal sales. At the same time, home production of grain with the aid of the tractor is less expensive per kilogram of grain harvest than is the purchase of grain. If one of the rules of the economic game in southern Tunisia is to minimize cash expenditure, then the choice in recent years is to produce more grain with the aid of the tractor. This option would be used before grain would be purchased. The shift to the tractor seems to be an unavoidable consequence of local economic strategies and of the limits imposed by the working rate of the camel and man.

The results of the chain of events outlined above can be seen in Fig.18.13. The height of each column reflects the average amount of land planted in grain during the study period. The proportion of surface area plowed by tractor and by draft animal is indicated for each year. The number of days needed to hand-plow the area is indicated inside the part of the column which refers to hand plowing. Next to each column is a time period (in days) which expresses the amount of time which would have been needed to plant all the land by hand.

The important trend in Fig. 18.13 can be seen by comparing the 2 latter years. Both times the family spent 12 days in hand-plowing efforts. But during the abundant year the family used the tractor to increase greatly the area of cultivated land. In this way the family can increase the amount of grain planted during a year when the expectation is for low probability of crop failure. Based on the above, one would expect that families would have hand-plowed all the grain fields in 1972-73. This is because the area falls well within the 5.6 ha limit which can be plowed by hand. The reason that some tractor plowing occurred is due to the recent reluctance of the family head to plow distant locations by draft animal. Fig.18.3 clearly illustrates the real importance of the tractor in the family's strategy to maximize grain production during years of low risk.

Evaluating alternate land-use strategies.-- It is clear that strong incentives exist within the system to maintain the present stategies of land use in southern Tunisia. The energy returns are high on investment of labor and cash in the local productive system. It will be difficult to find alternate land-use patterns which are simultaneously less destructive and also maintain an equally high return on investment. However, it is also fairly clear that if the present intensity of land use continues on the home base, desertization will render the entire area useless for years to come.

The analysis of this ecosystem is somewhat preliminary. Ecological research by the Tunisian PreSaharan Project is still in progress. It is therefore inappropriate at present to attempt to propose land-use changes which will retard or halt the ongoing process of desertization. However, based on present knowledge it is possible to suggest several characteristics of a potentially successful land-use alternative. Alternative strategies or resources should be no less efficient than present ones. The energy return on investments of cash, labor, and materials should be about as high as is the case for the present subsistence complex. The level of risk involved in the investment should be no higher than the risks associated with the current resource complex.

The standard used to judge land-use alternatives is the current land-use system. The present system works well from the point of view of the native Tunisian, although ecologically it is rather destructive. This paper has been concerned with a description of why and how the system works from an energetic and an economic point of view. The values of energy efficiency ratios and energy returns on cash investment can be used as standards with which alternate strategies should compare favorably if they are to be acceptable to the local inhabitants over the long term. Admittedly there are other important standards of acceptability of a proposed economic change. There are social and ideological aspects which have an important bearing on the acceptability and feasibility of alternate subsistence strategies. These attributes are still under study in the south Tunisian population and are beyond the scope of this paper.

One might argue that the energy ratios and returns in southern Tunisia are excessively high because the system does not operate on a sustained-yield basis. That is, a system operating only on an immediate return basis (ignoring the consequences for desertization) may be more efficient in the short run than a sustained-yield system which has no negative impact on the environment. This may be true. In that case the standard of judgment (the current efficiencies) is unreasonably high. Nevertheless, the most successful programs of economic development (from both the inhabitant's and the ecologist's point of view) will be those which can approach the energy returns of the present system while maintaining a sustained yield based on soil and vegetation stability. This standard of judgment is basically applicable to economic planning in all subsistence economies. The energy returns of a system must be determined before alternate strategies can be evaluated. A study of energy flow is uniquely capable of determining energy returns by combining energetic and economic points of view.

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CHAPTER 19

INTEGRATIVE SUMMARY

by Frederic H. Wagner

Comparative Analysis of the PreSaharan Ecosystem

Introduction.-- The Tunisian PreSaharan Project has been carried out from its inception with two long-term, strategic goals before it. The first has been the more applied and of potential value to Tunisia : To develop an understanding of the structure and function of the Djeffara ecosystem, including man's influence, in the hope of recommending land-use modifications which would abate the decline of productivity, and if possible, improve it. The second has been a more basic scientific one, and that has been to compare the structure and function of the Tunisian desert ecosystem with those of North American deserts. The Tunisian deserts have been used intensively for millenia while those of North America have been used less intenstively for little more than a century. Such a comparison might provide some indication of the effects of long-term, extreme perturbation on the structure and function of desert systems; of their ability to absorb such perturbation and responses to it; and of their ability to recover from it once the perturbations were eased or removed.

The two goals are synergistic, for both require thorough understanding. An understanding of any one system is often facilitated by comparison with others. Where comparisons disclose differences, they often lead to an analysis of causation, and a knowledge of causation obviously contributes to understanding. Hence in a very preliminary way in this summary, and more thoroughly in the on-going synthesis activities of the project, the Djefarra ecosystem will be elucidated in a context of comparison with North American desert ecosystems.

The physical environment.-- There are no perfect analogs of the Djefarra desert in North America. It exists in a Mediterranean precipitation pattern with most rainfall occurring between fall and spring. Its maritime conditions with proximity to the Mediterranean imply elevations near sea-level, high relative humidity (for desert conditions) and relative amelioration of temperatures and their day-night, summer-winter variations. The soils are conspicuously sandy.

In North America, the coastal deserts where maritime conditions are approached occur along the coasts of Baja California and the west coast mainland Mexico. These are generally classified as Sonoran Desert, with its biseasonal rainfall pattern, by North American ecologists. A small area of coastal desert occurs along the southwest coast of the Mexican state of Durango, and this is generally classified Chihuahuan Desert with its predominantly summer rainfall season.

The North American deserts which occur in a Mediterranean precipitation pattern are the Great Basin and the Mohave. The former exists at latitudes and altidues which produce much lower temperature, winter conditions that severely curtail plant and animal activity, and generally higher precipitation levels.

The Mohave Desert environment is the closest North American analog to that of the Djeffara by virtue of its precipitation seasonality and magnitude, and its temperatures. The climate of Las Vegas, Nevada is perhaps as similar to that of Chaabania as can be found among the Mohave weather stations with available data sets. The comparison is also facilitated by the proximity of Rock Valley to Las Vegas. Rock Valley has been one of the US/IBP Desert Biome research sites and large volumes of ecological data are available for comparison.

The latitude at Las Vegas is approximately 36°N, that at Chaabania approximately 33°. The mean, annual precipitation at Las Vegas is 111 mm, that at Chaabania approximately 100 mm. The man, annual Las Vegas temperature of 19.3°C compares with 18.3° for July 1975 through June 1976 at the Dar ez Zaoui weather station, as reported by Novikoff in Progress Report No. 5.

There are, however, some rather definite differences. One is altitude. Since the Mohave is a continental desert, existing in the rainshadow of the far western, North American Cordilleran Chains, altitude is the most important variable affecting the magnitude of precipitation. The 111 mm at Las Vegas is attained only by virture of its 630 m altitude. There are areas approaching sea level in the Mohave Desert, as in the vicinity of Death Valley. But in these cases precipitation falls well below the 100 mm level of the Chaabania area, as with the 45 mm mean at Death Valley.

A second difference is the more maritime conditions of the Djeffara and the continentality of the Mohave. Thus the mean, annual temperatures of the Dar ez Zaoui weather station and Las Vegas are similar, as mentioned above. But comparison of monthly, mean maximum and minimum temperatures of the two areas (Fig. 19.1) indicates that both winter maxima and minima are higher at Dar ez Zaoui, while summer maxima and minima are higher at Las Vegas. Thus seasonal variation is less marked at Dar ez Zaoui, with milder winter temperatures and less extreme summer temperatures. Furthermore, diurnal variation is more limited at Dar ez Zaoui. The average of the monthly mean maxima and minima differ by 10.3°C at Dar ez Zaoui, by 15.0° at Las Vegas.

Another consequence of the greater continentality in the Mohave is an extreme difference in relative humidities (Fig. 19.2). Daily maxima at Dar ez Zaoui seldom fall below 90%, even in the dry season. Daily maxima at Las Vegas are generally lower than the daily minima at Dar ez Zaoui and the Las Vegas minima are uniformly well below those of Dar ez Zaoui.

A third difference between the physical environment of the Djeffara desert and the Mohave-- and in fact all North American deserts -- is in the soil characteristics. The Djeffara soils are sands, while most North American desert soils are silts and clays. The extreme differences in

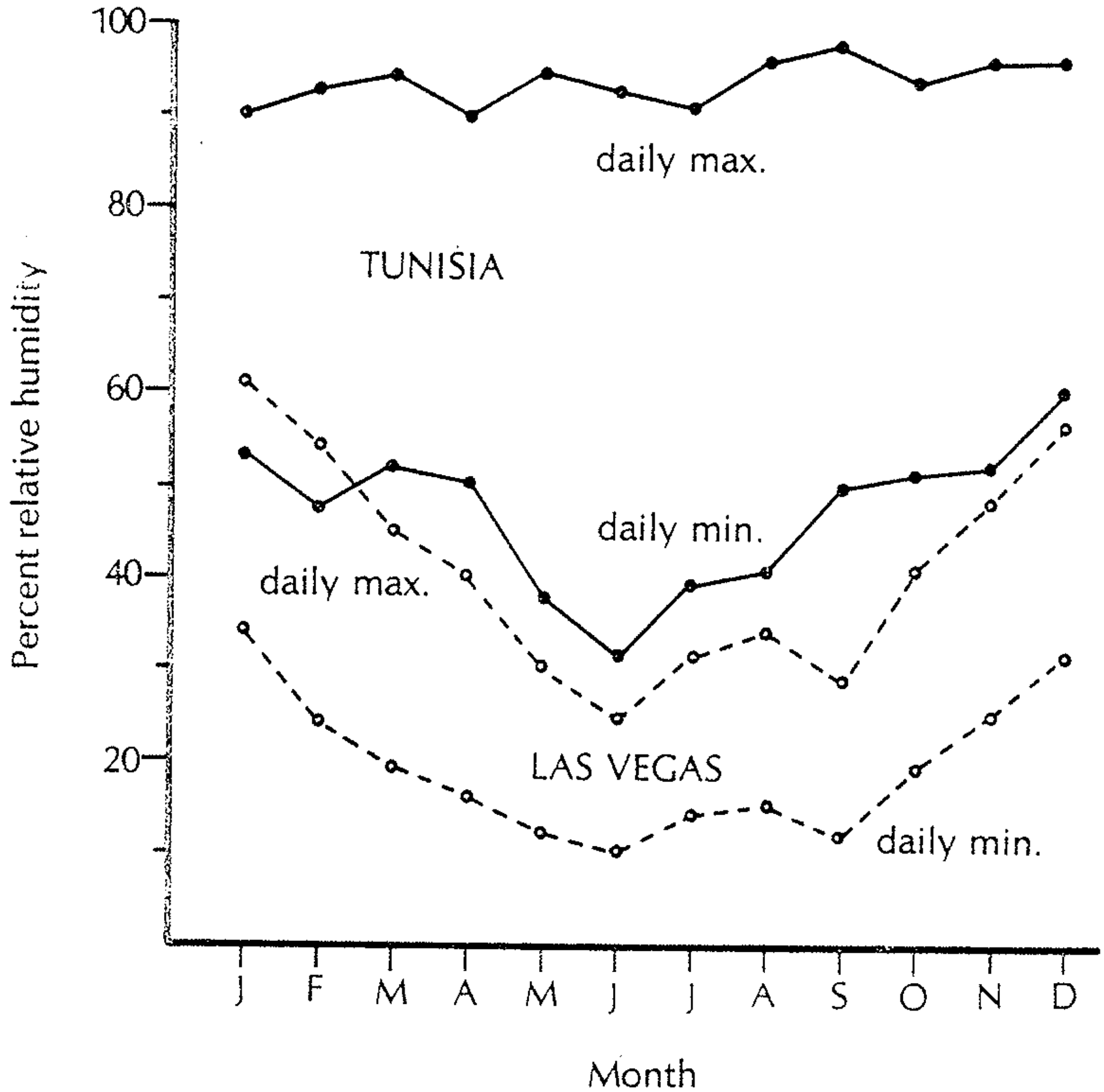

Figure 19.1. Monthly mean maximum and minimum relative humidities at the Dar ez Zaoui weather station (July 1975 through June 1976 reported by Novikoff, Progress Report No. 5) and at Las Vegas, Nevada (long-term means).

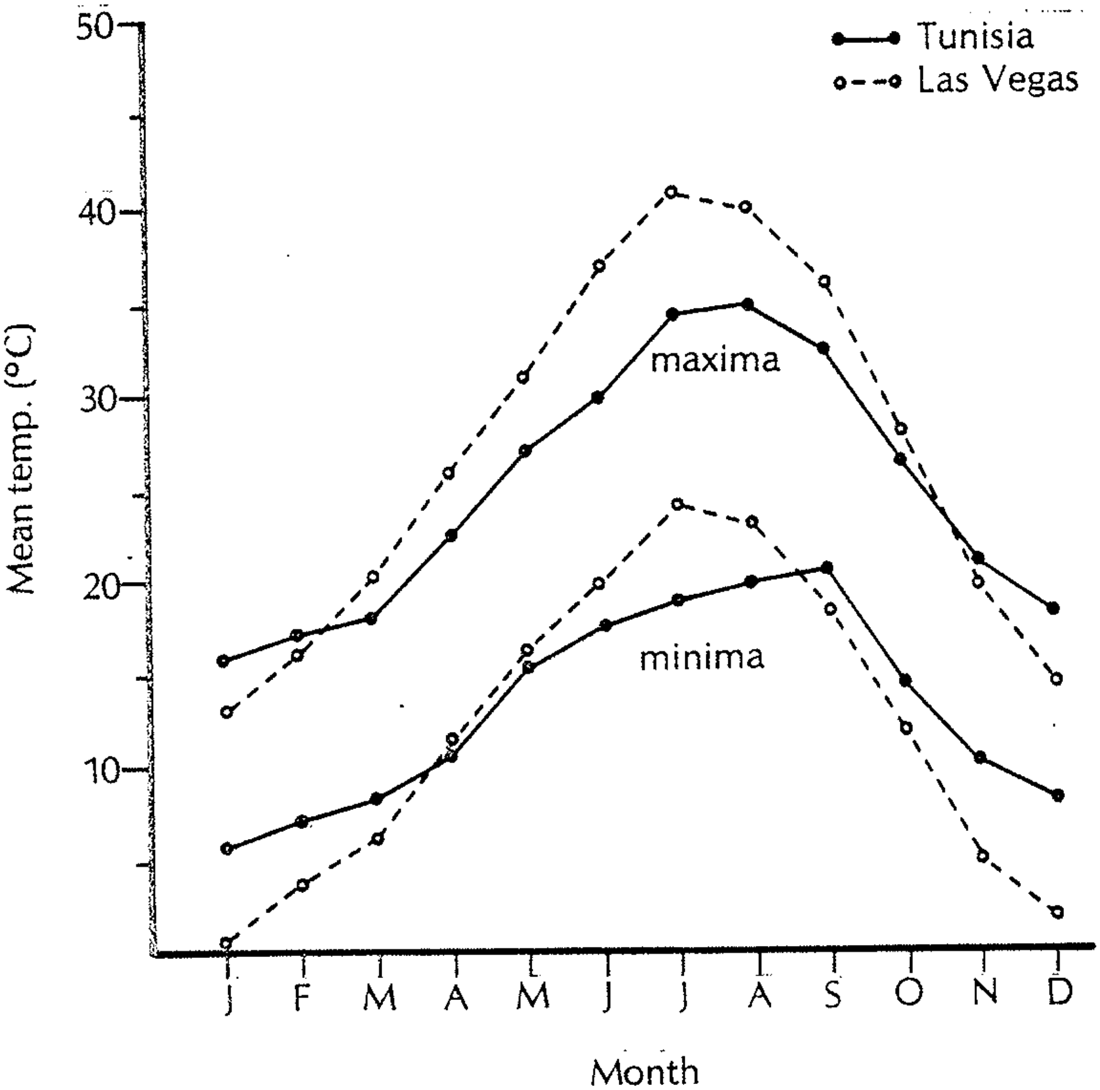

Figure 19.2. Monthly mean maximum and minimum temperatures at the Dar ez Zaoui weather station (July 1975 through June 1976 reported by Novikoff, Progress Report No. 5) and at Las Vegas, Nevada (long-term means).

chemical and biological properties have been thoroughly discussed by Skujins in Chapter 16, and need no further mention here.

The vegetation.-- Like the other comparisons being made, the vegetation comparison can only be a preliminary one. A major reason is that comparison of vegetation structure must await a full listing of Tunisian species for each year so that rainfall-related, annual variations in species richness and diversity of annual plants can be calculated. However, at this stage it appears that the Dar ez Zaoui vegetative diversity compares favorably with that of the Rock Valley. Novikoff's vegetation data in Progress Reports 2 and 3, and the Crocker-Bedfords' forage-preference data in this report (Chapter 10) have mentioned 25 species of annuals; 5 species of shrubs; 3 of large perennial grasses; 15 herbaceous perennials or half-shrubs (Novikoff's "small-sized perennials" and Crocker-Bedfords' "chamaephytes") and 5 species of biennials (Crocker-Bedfords' "hemicryptophytes"). This list of annuals may fall somewhat short of the approximate 40 species at Rock Valley, but the number of perennials probably exceeds the Rock Valley total.

Of particular interest is the comparison of net primary production. Since production in deserts varies so profoundly with precipitation, any comparison between areas and years must be made at similar precipitation levels. Figure 19.3 is a plot of total production measured during the 5 years at Dar ez Zaoui, and derived by adding the production of annuals, small-sized perennials, and Rhanterium reported by Novikoff in Chapter 2. The production values are plotted as functions of precipitation for each year. Also included in the figure are Desert Biome production estimates for perennials and annuals combined for 2 years at Rock Valley (Norton, 1974), a regression of perennial production on precipiation based on 13 years of measurement on the Desert Experimental Range in southeastern Utah (Hutchings and Stewart, 1953), and 2 years each of perennial and annual production measured in Curlew Valley, northern Utah (from Norton, 1974).

It is appropriate here to explain briefly the separation of perennials and annuals in the latter two cases. Both the Desert Experimental Range (D.E.R.) and Curlew Valley are in the Great Basin or "cold" desert region of North America. In this desert, annuals have not evolved as the conspicuous and abundant vegetative component which coexists with perennials, as they have in the southern or "hot" deserts in North America. Mature, undisturbed vegetation is comprised almost entirely of perennials, and hence the confinement of D.E.R. measurements to this type and separate presentation of the Curlew Valley perennial data. Where annuals do occur abundantly in the Great Basin, it tends to be in disturbed areas. Hence annual and mature perennial stands tend to be discrete vegetations-- separated in time as successional stages, of course-- and the production of each can be measured separately, as in the cases reported in Figure 19.3.

The results in Figure 19.3 suggest that total, net above-ground primary production at Dar ez Zaoui and in the North American deserts with winter precipitation patterns are quite comparable at similar precipitation levels. And the slopes of each attest to strong control exerted by precipitation over production.

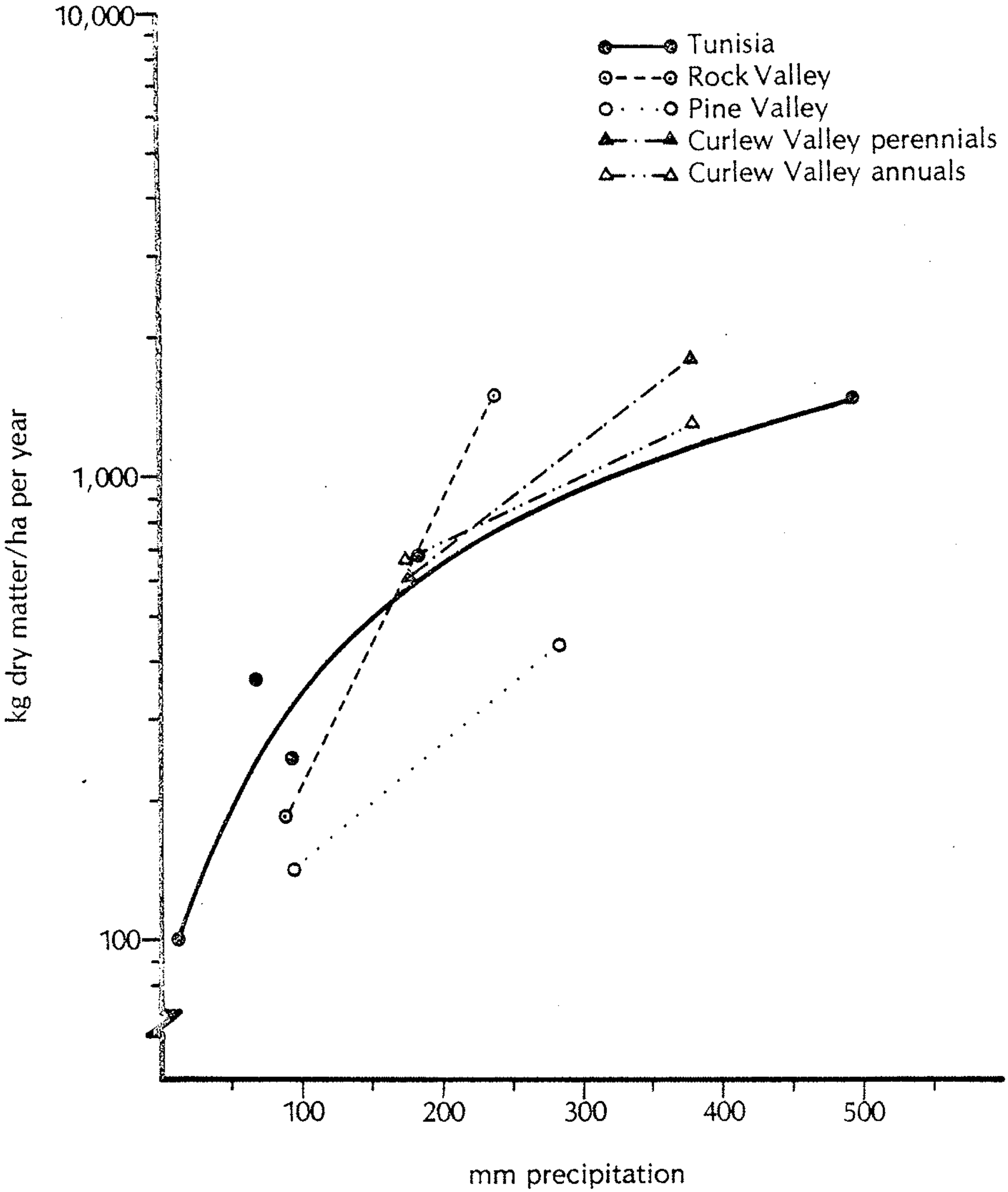

Figure 19.3. Net, annual above-ground primary production as a function of precipitation at Dat ez Zaoui and three North American desert areas (see text for sources). Dar ez Zaoui data are from Novikoff's Chapter 2 of this Progress Report.

It is of interest to examine the production-precipitation relationship in more detail. It is reasonable to postulate a more favorable moisture environment at a give precipitation level at Dar ez Zaoui than in the American areas by virtue of the much higher relative humidities and the sandy soils with their greater soil-moisture availability. Yet, Figure 19.3 shows no production advantage in the Dar ez Zaoui vegetation.

Since annual and perennial production depend on somewhat different processes--notably germination and seedling survival in the case of annuals--and therefore may display rather different moisture responses, it may be instructive to separate the two. In Figure 19.4, the regresssion for Rhanterium production presented by Novikoff in Figure 2.2 is plotted as a function of precipitation. The Rock Valley, D.E.R. and Curlew Valley perennial-production values shown in Figure 19.3 are also included.

The magnitudes of production are not of interest in this case because the Dar ez Zaoui and Rock Valley values constitute only a part of the total production on their respective sites. Rather, it is the slopes of the relationship that bear consideration here. In all cases, the slopes for the American deserts appear higher than that for Dar ez Zaoui Rhanterium. If true, these results suggest that a given increase in precipitation produces a greater increase in production in the American systems than in the Tunisian. Hence American desert perennial vegetation may be under relatively greater moisture restraint than the Tunisian; and this difference, if real, may result from an advantage conferred on the Tunisian system by the sandy soils and higher relative humidity.

One may then ask why, at a given precipitation level, total primary production is not higher in Tunisia than in the American deserts (Figure 19.3). A possible answer could be the extreme impoverishment of the Djefarra soils, as described by Skujins in Chapter 16. In that chapter he generalized that nitrogen is probably the second most important constraint on desert primary production, and this might be particularly true of soils as nutrient deficient as those of the Djeffara.

Standing crop and secondary production in livestock.-- What may prove to be the greatest difference between the Djeffara and the American desert systems is what seems to be emerging as an extremely high consumer biomass and secondary production. Since a major part of this is the livestock component, it needs to be considered in some detail.

Bedoian (Fig. 18.7) reports average livestock holdings per family of 11 adult sheep and 8 adult goats on 60 ha for the 3-year period 1972-73 to 1974-75. This is an average of 0.31 adult animals per ha. Both Bedoian and the Crocker-Bedfords (Chapter 5) reported that livestock numbers were increasing during the middle 1970's, and the Crocker-Bedfords reported adult livestock numbers (sheep and goats combined) varying from .73 animals/ha in September to .48/ha in May for the 3 years 1974-75 through 1976-77. A year-round average of 0.6/ha might be an appropriate estimate.

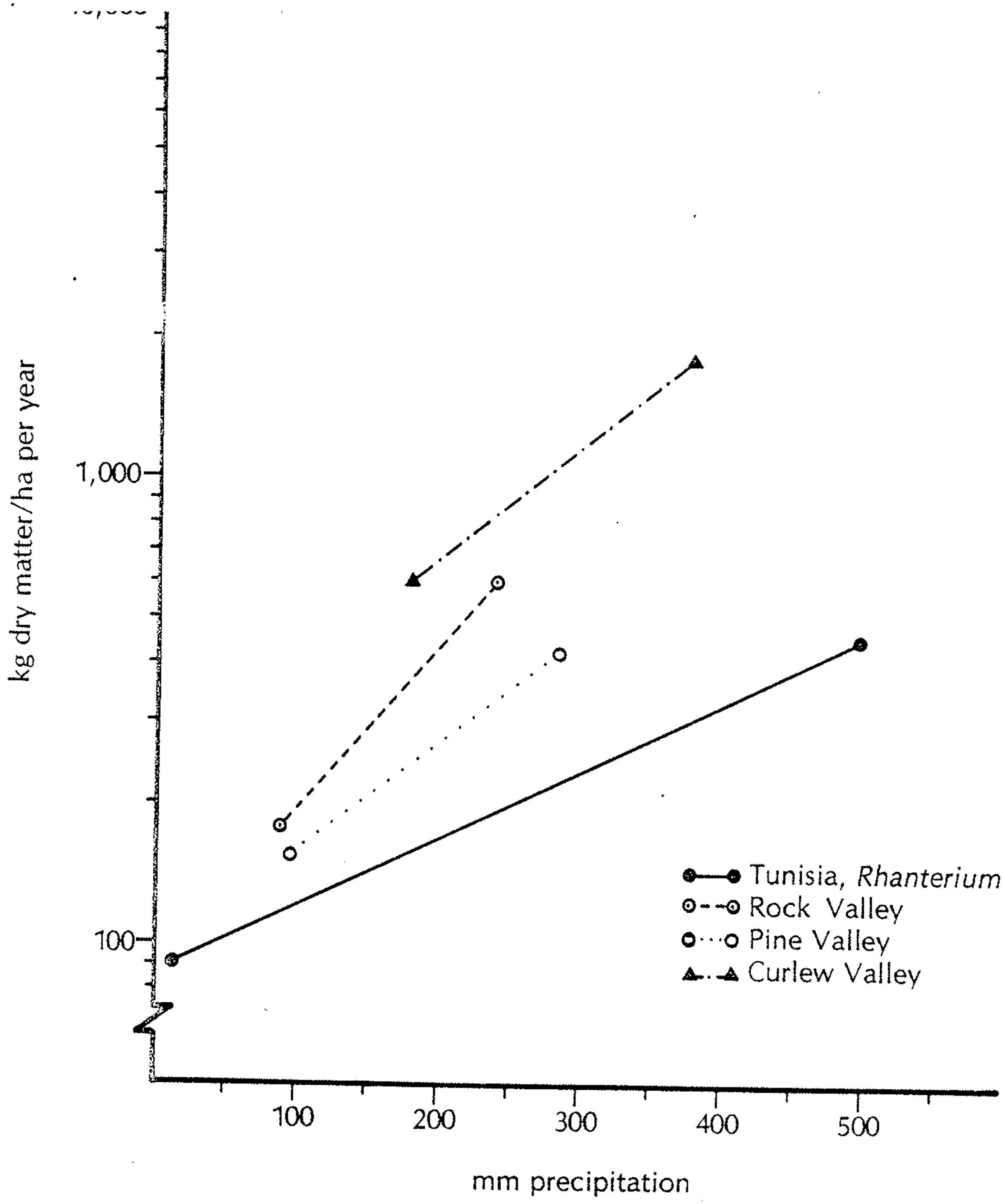

Figure 19.4. Net, annual above-ground primary production by perennials as a function of precipitation at Dar ez Zaoui and three North American desert areas. See text for sources.

Converted to a square-mile base, these values become 80/mi^2 for Bedoian's figures, and 155 for the Crocker-Bedfords'. In American range management, stocking rates are calculated in terms of animal units, with 5 adult sheep or 5 adult goats, with or without young, constituting 1 animal unit (A.U.). Hence the stocking rates in the Chaabania area are 80/5 = 16 and 155/5 = 31 A.U.'s/mi^2/year.

Comparison with American desert systems cannot be made effectively because (1) the Mohave Desert in the United States is generally considered too arid for livestock use; and (2) where it or the Great Basin are stocked with sheep, the use tends to be restricted to winter use with summer stocking generally occurring in mountainous areas. In the southernmost tier of states in western U.S. there is some year-round sheep ranching, and while these may be Sonoran (bimodal rainfall) or Chihuahuan (summer rainfall) Desert areas, some comparison is of interest.

The far western portion of Texas, termed the Trans-Pecos, is a large traditional sheep-ranching area with year-round use of the same range. Typical sheep stocking rates are 10-15 animal units per year: somewhere between the same, and one-third of, the Tunisian stocking rates.

One might argue that the Tunisian rates are artificially elevated by dietary supplementation. However, Bedoian's data (Fig. 18.7) show that only about 10% of the average, annual forage intake by Tunisian animals comes from cropland products. Furthermore, the Crocker-Bedfords' stocking rates are simply based on animals numbers per unit area of all land. Since grazing land occupies roughly 80% of the area in the average year, the actual stocking rate per unit area of grazed land is somewhat higher than the Crocker-Bedfords' estimate and this additional may simply cancel the effects of dietary supplementation. Hence, the Crocker-fedford's value is an appropriate estimate of stocking rates per unit area of grazing land and ranges somewhere between equivalent to, and 3 times as high as, the Trans-Pecos value.

Mean, annual precipitation of the Trans-Pecos varies from about 186 mm at El Paso on the west to about 400 mm in the eastern portion of the region. These values are roughly 2 and 4 times the Chaabania annual rainfall. Almost certainly the Trans-Pecos primary production is 2-4 times that of the Chaabania region.

Secondary production values can also be compared. The Crocker-Bedfords' (Chapter 15) calculate secondary production values for the Chaabania area at about 10 kg/ha, 80% of which is derived from lamb and kid growth, and 20% of which is derived from adult growth. Trans-Pecos secondary production in sheep can be calculated as follows:

(1) 10-15 A.U.'s/m^2 x 5 = 50-75 ewes/mi^2
(2) 50-75 ewes/mi^2 x .75 lamb crop = 37.5 - 56.3 lambs/mi^2
(3) at 37.5 kg av. wt./lamb, 37.5 kg x 37.5-56.3=1406-2111 kg/m^2
(4) 1406-2111 kg/mi^2 = 5.4 - 8.2 kg/ha
(5) 5.4-8.2 kg/ha is estimated production only in lambs. If we assume that production through adult growth is about the same proportion of total production as with the Crocker-Bedfords' Tunisian example (20%), then:

5.4-8.2 ÷ .8 = 6.8-10.1 kg/ha total secondary production

These values suggest secondary production levels in the Trans-Pecos slightly lower than, but approaching that of, the Chaabania region. The disparity derives from the higher stocking rates of the Chaabania area described above, and the higher lamb crops (0.75 in the Trans-Pecos vs. 0.86 at Chaabania). But the disparity is narrowed by the nearly 2-fold larger size of Texas lambs: 37.5 kg vs. 20-23 kg for Chaabania lambs and yet smaller size of Chaabania kids.

One condition tends to minimize the disparity. Trans-Pecos lambs go to market in early autumn while Tunisian lambs are removed from the range by May. While birth occurs some 2 months earlier at Chaabania, the fact remains that Texas lambs have remained on the range at least 2 months longer than the Tunisian. Hence, if production is calculated on a per-month basis, the Tunisian secondary production can be said to be definitely higher than that of the Trans-Pecos, perhaps half again as high. This higher Tunisian production derives from one-half to one-fourth the precipitation of the Trans-Pecos region, and in all likelihood comparable differences in secondary production.

Preliminary estimates of energy flow in the non-human components.-- Complete elucidation of energy flow in the Chaabania ecosystem awaits considerable analysis of data on the insects and wild vertebrates. However with several years of data on primary production reported by Novikoff, the data now available on livestock, Muir's data on insect biomass, and Bedoian's very thorough analysis of the human subsystem, a very preliminary, partial picture of energy flow can be attempted here.

Primary production: Novikoff's reports of this and the past 4 years provide an overview of vegetative production, and were used in part in his analyses of the moisture response in Chapter 2. The data may be summarized in Table 19.1.

The mean precipitation during this period (172.3) is substantially above the norm for the locale (ca 100 mm), and hence the mean production (559.6) must be above the long-term average for the area. Rainfall was closest to normal in 1973-74, and presumably so was the production. Perhaps 350 kg/ha would be a reasonable estimate of the long-term mean above-ground primary production.

This value is somewhat conservative because it does not include two shrubby species which, while not abundant at Dar ez Zaoui, still contribute some small amount. They are *Retama retam* and *Artemisia campestris*. However the research-site vegetation at Dar ez Zaoui is considerably more luxuriant than that of the surrounding area. Hence 350 kg/ha is probably somewhat in excess of typical production in the locale, even when computed without *Retama* and *Artemisia*.

Table 19.1

Above-ground Net Primary Production at Dar ez Zaoui for the Five Years 1972-73 to 1976-77[1]

Year	mm Total Precip.	Kg Dry Matter Produced per Ha			
		Annuals	Small-sized Perennials	Rhanterium	Totals
1972-73	15.3	29.2	17.1	81.4	127.7
1973-74	94.2	160.5	33.1	130.0	323.6
1974-75	186.4	440.0	43.9	242.1	726.0
1975-76	497.0	659.0	120.5	465.0	1,244.5
1976-77	68.6	68.4	74.3	233.3	376.0
Means	172.3	271.4	57.8	230.4	559.6

[1] Data from Georges Novikoff in Progress Reports 4 and 5 and Chapter 2 of this report.

The 1972-73 values (127.7) and that for 1975-76 (1,244.5) give some idea of the range of variation around the mean, those values differing by a factor of roughly 10.

<u>Livestock forage consumption</u>: Two sources are available for estimating consumption. Bedoian in Figure 18.7 lists an average annual consumption by sheep and goats of 10,333,000 kcal of pasturage and 3,679,000 kcal of hand-plucked natural vegetation (his "fodder") for a total of 14,012,000 kcal. This is digestible energy (Bedoian, Personal Communication) and if we assume a 65% assimilation efficiency, the total vegetation consumption in energy equivalents is 14,012,000/.65 = 21,556,920 kcal on 54 ha of land in the Chaabania locale. On a per-hectare basis, this becomes 399,202 kcal.

On the basis of 4 kcal/g of dried plant material, the consumption is approximately 100,000g or 100 kg. This is approximately 29% of the average annual primary production at the Dar ez Zaoui research sites and undoubtedly a somewhat larger fraction of production in the surrounding terrain.

Furthermore, Bedoian's 1972-73 through 1974-75 stocking rates were only about half those reported by the Crocker-Bedfords (Chapter 5) for the past 3 years. However, primary production in 1974-75 was about twice normal, in 1975-76 nearly 4 times normal, and about normal in 1976-77 (Table 19.1). Given the Crocker-Bedford's stocking rates and Bedoian's livestock consumption rate, forage consumption may have been about 200 kg/ha/year and constituted about 28% of primary production in 1974-75, about 16% in 1975-76, and about 53% in 1976-77. If the stocking rates reported by the Crocker-Bedfords continue to hold yearly,forage consumption may be well over 50% of the long-term mean,annual above-ground primary production.

A second means of estimating consumption is on the basis of Griego's forage-consumption estimates (cf. Progress Report No. 4). His estimates for consumption during the month of April, and based on fecal collection and digestibility trials, varied from 1.5-2.9 kg of dried plant material per day for adult sheep and 1.5-1.9 kg/day for adult goats. During summer when temperatures are higher and forage quality is lower, consumption is undoubtedly reduced by an unknown amount. Perhaps 1 kg/day and 365 kg/year is a conservative estimate for a year-round average per animal.

Bedoian's estimate of 0.31 adult animals per ha would suggest average consumption of 0.31 x 365 = 113 kg/year, a value very close to his own estimate. If the Crocker-Bedford stocking rates prevail, then forage consumption is about double Bedoian's or 2 x 113 = 226 kg/year. The former value implies a long-term average consumption of about one-third the Dar ez Zaoui primary production, the latter value implies about two-thirds.

These values are conservative because they do not take into account lambs and kids. Born in winter, these young animals initially subsist only on milk. But within a month or two, they are beginning to graze some vegetation and by spring are consuming a substantial fraction of what the adults are taking. The animals are sold by May and hence their consumption is ended. But for a period of 4-5 months, they have added to the consumption total to an unknown degree.

Because of their consumption, because the daily rate may be conservative, and because the research site primary production exceeded that of the surrounding terrain, the above estimates are in all probability conservative. It is difficult to escape the impression that livestock over a long-term average consume half or more of the net primary production of the Chaabania grazing lands.

Fuel gathering: The local people gather vegetation for fuel. According to Bedoian (Personnal Communication) this has not been measured directly, but a crude estimate can be made by analogy with the gathering of wild fodder. The latter occupies about 2 hrs per day for a 20-day period in spring. During this time, some 3,679,000 kcal are gathered on 54 ha in the average year (cf. Fig. 18.6). This becomes 3,679,000/54 = 68,130 kcal/ha, and divided by 4 kcal/g becomes 17,032 g or 17 kg/ha. Gathered over 40 hrs, this total computes to 17/40 = .43 kg/hr.

Fuel material, according to Bedoian's observations, are gathered during about 6 hrs per week, or for a total of 312 hrs per year. If fuel material is gathered at roughly the same rate as wild fodder (khortan), the total obtained is 312 x .43 = 134 kg/ha/year. Much of this is, of course, older growth. But it constitutes more than a third of average, annual, net primary production. When added to livestock forage consumption, the total removal becomes a sizeable fraction of annual production.

Invertebrate considerations: As mentioned in Muir's Chapter 14, considerable analysis remains before energy flow through the invertebrates can be meaningfully analyzed. But some manipulation of his numbers provide some estimates which are conservative, but nevertheless interesting, food for thought.

Since we are synthesizing an energy-flow picture for the heavily grazed lands of the Chaabania locale rather than that over our more conservatively grazed research site, the figures of interest are Muir's data in Table 14.2 of this report on what he calls Area 6, the heavily grazed area adjacent to the Dar ez Zaoui research site.

These are standing-crop estimates, not truly production estimates. But because most insect species turn over a complete generation within a year, we would not go far astray by taking these biomass estimates as having been produced within the year they were made. Therefore they are in actuality production estimates for the year of measurement.

The seasonal biomass estimates cannot be summed for our present purpose to provide production approximations because some species persist through two or more seasons. Some species and presumably some individuals, measured in spring will also be present in summer, and to use their biomass in both seasons would improperly duplicate their production. One means of avoiding this problem is to use the Muirs' and Heatwole's estimates of seasonal overlap (Progress Report No. 5, Table 3.8). Their data indicate which fraction of the species measured in any one season are unique to that season. If the monthly biomass totals in Table 14.2 of this report are multiplied by the fractions of seasonally unique species, the products can then be summed for the year and duplication avoided. These are as follows:

Table 19.2

Dry-Weight Biomass of Herbivorous Invertebrate Species Unique to Each Season in Muir's Area 6[1]

Season and Year	G/Ha[1] (1)	Fraction of Species Unique to Season[2] (2)	G/Ha of Unique Species (1x2)
1975			
Spring	1,427.8	.72	1,028.0
Summer	754.6	.70	528.2
Fall	1,529.8	.39	596.6
Winter	3,178.2	.45	1,430.2
Total	6,890.4		3,583.0
1976			
Spring	2,201.1	.72	1,584.8
Summer	3,543.8	.70	2,480.7
Fall	2,579.3	.39	1,005.9
Winter	2,668.2	.45	1,200.7
Total	10,992.4		6,272.1

[1]From Muirs' Chapter 14 of this Progress Report.

[2]From Chapter 3 of Progress Report No. 5 by Muir, Muir and Heatwole.

Thus, a first approximation of secondary production in invertebrate herbiovires is 3.6 kg/ha/yr for 1975 and 6.3 kg/ha/year for 1976. These are conservative for two reasons. The first is that they are only based on species which occur in a single season. They do not include species which occur in two or more seasons. Hence a better estimate would be somewhere between these values and the yearly totals (Column (1) in Table 19.2), with values of 6.9 and 11.0 kg/ha/yr for the 2 years. A second reason why the estimates are conservative is that they make no provision for those individual organisms which died between hatching or birth, and the time the populations were sampled and biomass estimates made.

Thus, while these values are highly provisional, it appears possible that secondary production of invertebrate herbivores in 1975 and 1976 approached, or conceivably exceeded, that of livestock in these same years. Since precipitation in 1975 and 1976 was above average (Table 19.1), and since the invertebrate studies have shown correlations between annual precipitation and annual invertebrate production, the average invertebrate production over a period of years would be somewhat lower than the two sets of values calculated above. Nevertheless, even in the average year, invertebrate herbivore production may approach a sizeable fraction of livestock production in heavily grazed areas.

What these values imply in terms of vegetation consumption must await further analyses of the invertebrate data. That invertebrate production approaches livestock production does not imply that their consumption rates are comparable because poikilothermic species have considerably higher growth efficiency than"homoiotherms. Hence the mass of invertebrates produced per mass of vegetation consumed is higher than the same ratio for large, grazing mammals.

Nevertheless, the high invertebrate production implies a substantial vegetation consumption which adds further to the already extensive vegetation use by livestock grazing and fuel gathering. Once the consumption of herbivorous small mammals and of granivorous birds are added to the total, there seems little doubt that over a period of years, average vegetation removal by all users approaches, or conceivably exceeds, average primary production. If the vegetation is gradually degrading, as we believe to be the case, this is obviously a result of, and indicates, excess of consumption over production.

Since Muir's Chapter 14 also provides biomass data on detritivores and carnivores, it is of some interest to perform the same calculations on these groups as we did with the herbivores in order to consider the order of magnitude of total invertebrate production. With the same procedure used for the herbivores, these values become, again for the grazed area:

	Conservative Estimate	Cummulative Annual Biomass
1975 Detritivores	7.9 kg/ha	15.7 kg/ha
1975 Carnivores	1.2 kg/ha	2.0 kg/ha
1975 Total	9.1 kg/ha	17.7 kg/ha
1976 Detritivores	6.7 kg/ha	12.9 kg/ha
1976 Carnivores	2.8 kg/ha	5.7 kg/ha
1976 Total	9.5 kg/ha	18.6 kg/ha

When these values are added to the herbivore values of Table 19.2, it becomes evident that total invertebrate production substantially exceeded livestock production in these 2 years which itself is already quite high by North American standards. The contrast thus grows of two desert systems with comparable primary production, but with much higher secondary (and probably tertiary) production in Tunisia than in North America. This difference in production follows from perhaps complete utilization of net, annual primary production in Tunisia, but less than 10% utilization in North American deserts (Wagner, 1976) and in fact most terrestrial ecosystems.

With the near-total utilization of annual production, Skujin's soil descriptions can now be understood. There is simply none left to add organic matter to the soil, and hence the exceedingly low organic content. Furthermore, the annual removal from the land of khortan, a large animal crop, and fuel must constitute a sizeable nutrient drain. Over a long period of time, and in the absence of fertilization, one would expect the low inorganic nutrient content described by Skujins.

Stability properties of the system.-- In view of this intensive use, and the traditional, ecological view that desert systems are brittle (change markedly under perturbation, respond slowly and weakly once the perturbation is removed), what can be said at this stage about the stability characteristics of the Djefarra ecosystem?

To begin with, the system appears as diverse as North American deserts. As mentioned above, vegetative diversity appears comparable with Mohave Desert vegetation. With more than 1,000 species of invertebrates cataloged by the Muirs, Heatwole, and Davidson, the invertebrate fauna appears fully as diverse as that of the Mohave. And the same is probably true of rodents, birds, and reptiles.

Furthermore, the system appears to be highly resilient (responds promptly and markedly to removal of perturbation) as was reported in some detail in Progress Report No. 5. The mechanisms of this resilience constitute a fertile ground for research, and probably lie in the demographic and physiological strategies of the species. Detailed analyses of these are beyond the scope of this study. In part it may result from the lesser moisture constraint discussed earlier. Also fruitful ground for future research are the circumstances promoting the much higher primary consumption and secondary production than are characteristic of western hemisphere, terrestrial systems.

However, a major practical significance of the resilience is the promise it holds for improving land management. Novikoff's studies have shown the system to be highly responsive to land-use modification, as he discussed in Progress Report No. 5. There is little doubt that a properly conceived management program would abate the decline of the system, and in all probability improve its productivity. In all likelihood, the already substantial livestock production could be enhanced.

Implications of the Human Biological Studies

Implications for improved land-use practices.-- Bedoian's superb analysis provides a detailed insight into the sources and magnitudes of sustenance for the culture, and the costs and modes of providing that sustenance. His production efficiencies, which could equally well be termed benefit/cost analyses, show ways in which the efficiency of the economy could be improved. Thus, under present cost structures, grain production is far more efficient than olive production. Since the latter is in Bedoian's view, the most damaging use of the land, one possibility for improving the land-use pattern while at the same time enhancing the people's productivity would be to change areas now in olive production to grain production.

One set of statistics which stands out as potentially important is the contribution of livestock production to the total family economy. Meat products, both through direct use, and through sale which enables market food purchases, collectively contribute 1,332,000 kcal per year (Fig. 18.7) toward the family's annual need of 3,502,000. This is only slightly more than a third of the annual need, yet it is produced off 78% of the land area. Or on the contrary, nearly two-thirds of the family's need is produced on 22% of the land area, mostly with small grain. If efficiency were calculated on the basis of caloric production per unit area of land, pastoralism is only about one-sixth as efficient as grain cultivation.

Here again differences in efficiency present some possibility for improved land management. A 50% increase in the relatively minor fraction of land now under cultivation would provide the same family income as now provided by livestock, make the family less dependent on the latter, and perhaps make possible a reduction in stocking rates, at least on a temporary basis until better grazing systems could be installed. With improved economic status of the family, there would be less need for such marginal products as grain straw, and farmers could perhaps be encouraged to leave stalks in the fields to provide the soil protective measures which Novikoff explores.

As mentioned in Progress Reprot No. 5, it seems likely that fertilization would be a worthwhile investment. In view of the extreme poverty of the soil, it seems almost certain that fertilizer amendment would yield a favorable benefit/cost ratio.

In total there appear to be several routes-- improved range-use patterns, shifts in cropping patterns, fertilization-- which could both improve the economy of the people and lead to improved land conservation. Both would appear to go hand in hand, for in a bare subsistence culture, it is difficult to ask people to exercise restraint in their pressures on the land; in a barely viable economy, there is hardly a margin which could go into investments that realize long-term dividends. Some priming in the form of funds for tractor rental or fertilizer purchase, might be needed to provide this margin.

Is change possible?-- The naive westerner may question whether changes like those speculated on above are possible in a traditional culture which still maintains a life-style similar in many ways to what it has been for centuries. Or it may ask whether Eastern existentialism will accept the restraint of investing today in some activity that will realize benefits only at some date in the future. The answers to these questions can already be given tentatively on the basis of experience to date.

To the first, one may reply that change is already evident. What a few generations ago was a nomadic lifestyle is now a largely sedentary one, with all its implications for land misuse in a desert region. The population is growing with its implications of smaller and smaller family land holdings, smaller livestock holdings per family, and the increasing difficulty of providing family needs on the reduced land holdings. Bedoian's data show that the family economy can no longer be balanced through present land-use patterns, and is balanced only with input of wage labor secured outside the system. That labor is itself a change. Growing tractor use is another form of change. In Bedoian's view (Personnal Communication) the entire system is in transit from a pastoral culture to one of predominantly cultivated agriculture.

In the final analysis, it seems clear that the people will, like people everywhere, change when they perceive that change to be in their own self interest. There is considerable lore about what is favorable land-use, and as with people everywhere these views, traditions, and beliefs are not always correct. If they can be shown through demonstration that some of their ways could be improved upon, there is little doubt that they would change. But it would seem that change is most likely to come about through demonstration and emulation at the grass-roots level, rather than by bureaucratic fiat.

To the second question of restraining consumption today for a gain in the future, there would already appear to be an answer to this as well. Planting an olive grove which will not bear for several years is such a long-range investiment. Placing grain in reserve following a bounteous harvest in order to provide insurance against a dry year, as reported by Bedoian, is another example of restraint. But again that restraint quite reasonably must be perceived as being in their own self interest.

The Importance of Research

This research project has been underway for 5 years. Only in the last year or 2 are implications of that research beginning to indicate promising leads for improved land management. These leads emerge from the growing understanding of the biota (including domestic animals), the physical environment (especially soil physico-chemical processes in relation to the biota), and socio-economic patterns of the culture.

Whether or not these leads can be actualized into generally accepted land-use practices depends on two contingencies. The first is their correctness. At this stage they range from preliminary hypotheses to reasonably well established patterns, and before they could be recommended unequivocally they need a period of trial on an experimental basis. Hence the next stage is a period of experiment and demonstration undoubtedly involving several years.

The second contingency is whether or not the culture will ultimately accept the land-use modifications recommended to them. Such acceptance would seem to depend on a period of demonstration, education, and extension; and close personal involvement with the people.

The leads now emerging from the research are few in number. Undoubtedly others will emerge in the next year or 2 after the findings of this project are fully analyzed and interpreted. With expansion or extension of the research, leads to other land-use recommendations would undoubtedly emerge.

The main purpose in belaboring these obvious truisms is to emphasize that recommendations for improved land management do not arise _de novo_, but rather from a detailed understanding of the systems for which they are proposed. There is no short-cut to that understanding that can by-pass the intensive research effort needed to provide it. Alternatively, ecological and social systems are so varied that generality does not appear at his stage of our understanding to be a fruitful source from which to derive specific land-management programs for the many climatic, biotic, and social nuances that exist in the world. Details of climate, soils, livestock types, land-use patterns, and cultural modes exhibit a rich array of variation. There would seem to be no alternative but to make the commitment to research programs designed to provide the understanding of at least many of the bio-cultural ecosystems known to man.

There is in recent years an unfortunate reaction against research in many quarters of the world . (Several reasons seem evident, but are not appropriately discussed here.) A recent example was the planning policy of the 1977 world desertification conference at Nairobi. In general the _de facto_ theme was that sufficient research has been carried out, and the conference should address itself to getting on with action programs for solving the world's problems of desert expansion.

Of course, no one would argue that we should not proceed with action programs in those cases where our knowledge permits. Clearly we must. The only contention here is that in many, perhaps in a majority of cases we do not have the intimate understanding that well-conceived programs required. It would be most unfortunate if we entered an era with the general view that we have conducted enough research, no longer need a general commitment to it, and need now only get on with the job of implementing management programs. The result of such a view could well be the failure of many of those programs.

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PART V

APPENDIX