AN ABSTRACT OF THE THESIS OF

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The need for classifying vegetation in a more precise way is evident. Also, there is a need to provide a hierarchical classification scheme that will match changes in image characteristics as one moves through the scales from space to conventional aerial photography. Such refined classifications of vegetation are the first steps toward a better understanding of the potentialities and limitations of a specified area which help in the detection of analogous environmental conditions for resource allocation and management purposes. These needs become more urgent as use and competition for natural resources and land increases. The first approximation of a classification scheme may meet these needs for a test site in the Tombstone, Arizona, vicinity. This classification task was

accomplished by the use of a "hierarchical-polythetic-agglomerative" package using presence-absence data and standardized cover estimates.

The following tentative associations and a variant were found upon division of the original data into groups of convenient size to meet the limitations of the programs:

- Association A (*Panicum hirticaule*/*Tidestromia lanuginosa*-*Boerhaavia coulteri*)
  - Ia (a variant of Association A)
- Association B (*Rhus microphylla*-*Dalea formosa*)
- Association C (*Gutierrezia sarothrae*/*Eriogonum abertianum*)
- Association D (*Menodora scabra*/*Tridens grandiflorus*)
- Association E (*Hilaria belangeri*)
- Association F (*Gilia rigidula*-*Rhynchosia texana*)
- Association G (*Hilaria mutica*/*Eriochloa gracilis*/*Crotalaria pumila*)
- Association H (*Haplopappus tenuisectus*/*Eragrostis lehmanniana*)
- Association I (*Ayenia pusilla*/*Eragrostis intermedia*)
- Association J (*Cnidoscolus angustidens*)
- Association K (typical association lacking character species) of Alliance III (*Fouquieria splendens*-*Acacia constricta*-*Aloysia wrightii*)
- Association L (*Agave palmeri*-*Agave parryi*/*Haplopappus laricifolius*)
- Association M (*Mortonia scabrella*)

These were grouped by the classification into units of higher rank. Association (A), (B), and the variant (1a) grouped into an alliance with the character species, Acacia vernicosa-Larrea tridentata-Flourensia cernua. Associations (C), (D), (E), and (F) grouped into the Yucca elata/Bouteloua eriopoda Alliance; and Associations (I), (J), and (K) were held together in an Alliance by the character species, Fouquieria splendens-Acacia constricta-Aloysia wrightii.

Validity of the character and differential species as association and subassociation "identifiers" was tested by the use of stepwise discriminant analysis. Two hierarchical levels and two runs per group were carried out using this analysis. A perfect discrimination between or among the groups was found at all levels except one. Species identified as differential or character species in the classification process were found to be the best discriminants. This suggests that the vegetation units identified by these species are valid.

The "hierarchical-polythetic-agglomerative" approach to vegetation classification provides the kind of framework which is compatible with the classical phytosociological techniques of vegetation study. It eliminates, however, the cumbersome task of hand sorting and tabulation and increases the capacity of complex operations as well as introduction of more systematic and thorough evaluation into the analysis. This approach of classifying vegetation appears to be suited for survey-type studies in areas where vegetation information is limited and the need exists for an initial classification in order to begin more comprehensive quantitative studies. This does not preclude using the method for other purposes. Because it is a hierarchical method, one can go into as much classification detail as is dictated by the purpose of the vegetation study. This last feature is well suited to the use of the results in interpretation of multiscale photography so important in the field of resource analysis.

Research needs to be done to answer the very fundamental question of why Euclidean distance (as a measure of similarity) and Ward's method (as a sorting strategy) provided a more adequate hierarchical classification scheme when presence and absence data are used rather than standardized values. Research is needed on the most effective criteria to divide large data sets into groups of the appropriate size.

Results of this classification now need to be tested by practical field use in the recognition of ecosystems and their mapping on appropriate scales of remote sensing imagery. To aid the practical user of this information, a dichotomous key to the phytosociological classes was developed. This requires the recognition of 8 species to make classifications at alliance level and 32 species to achieve the association separations. A key for subassociation level was not prepared because the practical value of this level is somewhat in doubt.

A Preliminary Vegetation Classification of the Tombstone, Arizona, Vicinity

by

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A PRELIMINARY VEGETATION CLASSIFICATION OF THE TOMBSTONE, ARIZONA, VICINITY

INTRODUCTION

The words land-use and planning are and will continue to be increasingly meaningful for all involved in the allocation and management of the natural resources. These words appeal to public officials, administrators, resource-oriented people, and the general public as a result of increasing demands on resources by an ever expanding number of users. Time has come for a comprehensive inventory of every natural resource to set priorities, establish policies and guidelines which will determine the most appropriate use and management of these resources.

The need for these inventories has been recognized but the approach to follow is still in doubt. There have been overwhelming disagreements among ecologists on how to record the vegetation, one of the basic elements of a natural resource area. A fundamental premise of people involved in vegetation studies is that the vegetation expresses the effects of the total environment. The choice of qualitative or quantitative data to study vegetation depends very much on the objectives one has in mind. It is generally believed that qualitative data, such as presence and absence, provide enough information for a first approximation of a classification in the study of vegetation.

Quantitative measurements are more effectively used for studies in depth after the major vegetation components of an area have been identified.

Some of the products of modern technology permit the ecologist to work more effectively in characterizing and explaining the vegetation and its significance in land use and resource management. These include the computer and new developments in remote sensing. As a member of a team concerned with remote sensing applications in vegetation and related resource evaluation, I found it necessary to improve upon the understanding of vegetation description and classification in southeastern Arizona. In the use of photographic remote sensing for vegetational inventory, it is essential to relate images to consistent and repeatable vegetational classes. The multiple scales at which photography can be taken is also suggestive of the importance of developing hierarchical classifications of vegetation. It was found that presently available vegetation studies in our area did not treat the vegetational classes with sufficient detail for in-depth studies of the consistency and refinement with which high quality aerial photo images could be interpreted. In an attempt to meet these needs I undertook a study in southeastern Arizona to more adequately characterize and classify the vegetation of a restricted study area in the vicinity of Tombstone, Arizona.

This study was, therefore, undertaken in support of a much larger remote sensing project. The basic thrust of my study was to apply basic phytosociological and numerical classification principles in developing a better understanding of naturally vegetated landscapes. The objectives were:

1. To analyze, recognize, and classify the vegetation of the study area by a numerical approach, hierarchical classification, developed by Dr. W. T. Pyott (1972) of our staff using presence and absence data and standardized cover estimates.
    a) To test the usefulness of the approach in the detection of individuals or group of indicator species which may be referred to as character and differential species in the phytosociological context.
    b) To determine the validity of the character and differential species for the identification of the vegetation units resulting from the classification procedure by the use of the stepwise discriminant analysis (SDA).
2. To amplify the taxonomic unit legend developed by the Oregon State University Range Management staff to a highly specific level of classification.

DESCRIPTION OF THE STUDY AREA

Location

The study area is located in southeastern Arizona, in Cochise County. It lies between parallels 31°34' and 31°47' and the meridians 109°52' and 110°05', within the boundaries of the townships 19, 20, 21S and the ranges 22, 23, and 24E. The area included in the present study is approximately 164,144 acres and is shown in Figure 1.

Climate

The area has a warm and semiarid climate (BSh) according to the climatic classification proposed by Sellers (1960). Sixty years of records show that the mean July temperature was 79.0°F, and the mean January temperature was 47.7°F, with a mean annual temperature of 63.1°F. Smith (1956) has reported a frost-free season of 239 days.

Records for a 57-year period show that the mean annual precipitation was 14.5 inches for the Tombstone rain gauge. According to Green and Sellers (1964) this is very close to the average for the entire study area since most of the area falls above the ten inch isohyet. However, an examination of rainfall distribution information for the Walnut Gulch Watershed (Osborn and Reynolds, 1963; Agricultural Research Service, 1967; Osborn and Hickok, 1968;

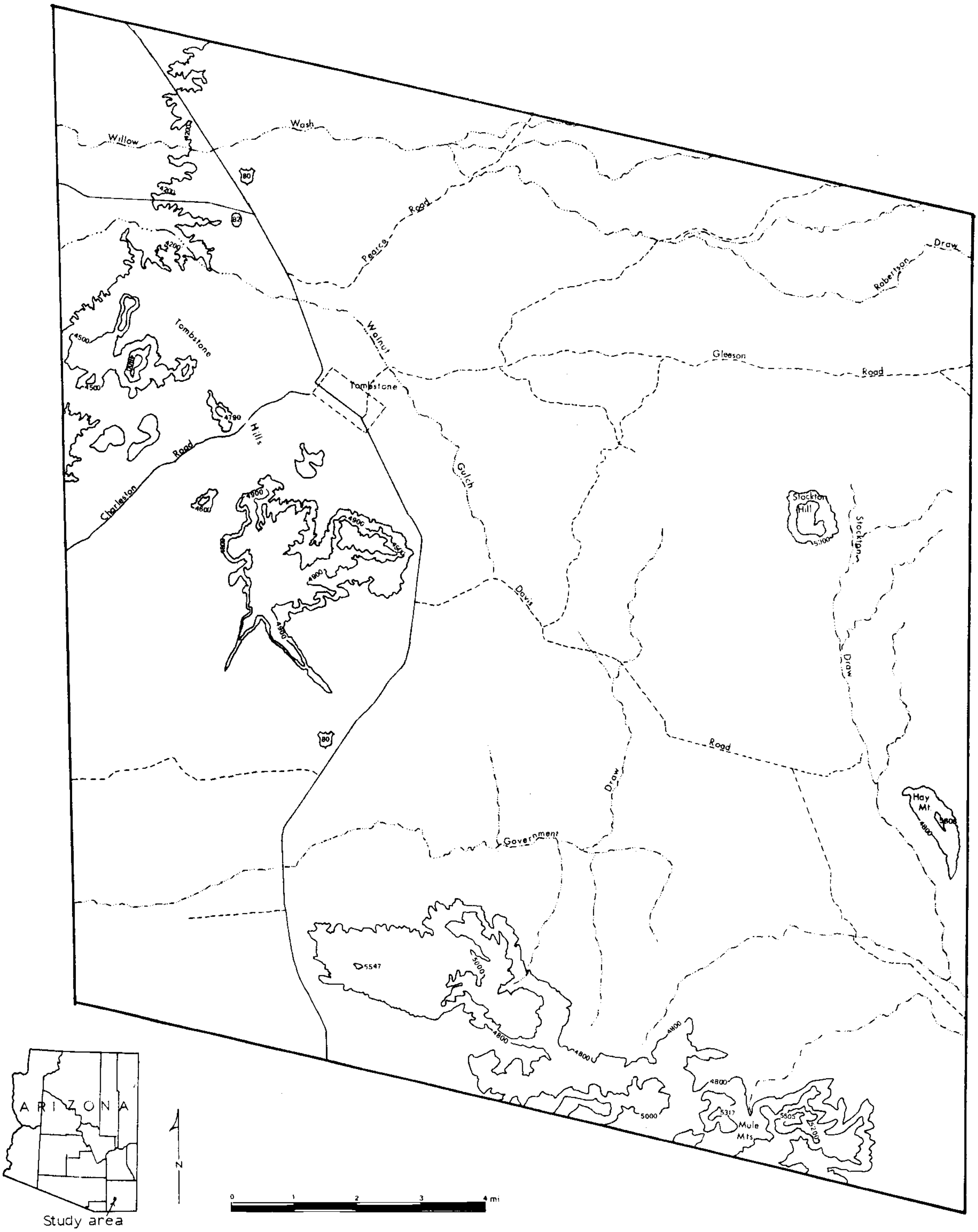

Figure 1. Location of the study area.

Renard, 1970) indicates considerable variation in precipitation within the area. This variation ranges from seven inches in two gauges located in the southern edge to 16 inches at two points located on the western part adjacent to the Tombstone Hills. Similar variations are expected to occur in the remainder of the study area where no precipitation records are available. More than 50 percent of the rain comes in the form of heavy thundershowers of short duration and high intensity during July, August, and the first half of September. The rest of the precipitation, except for the driest months of April, May, and June, is evenly distributed.

Physiography, Geology, and Soils

The study area is located in the Arizona upland portion of the Basin and Range Province (Wilson, 1962). The area can be divided into four physiographic areas as delineated in Figure 2. A generalized description of the physiography, geology, and soils of each of the mapping units of Figure 2 is given. Gilluly (1956) and the Arizona Bureau of Mines (1959) were used as references for the geology. Gelderman (1970) was the source of the soils information summarized below:

Mapping unit 1a comprises flat, smooth lands which occur in areas of Quarternary gravel, sand, and silt alluvium. The major associated soils include:

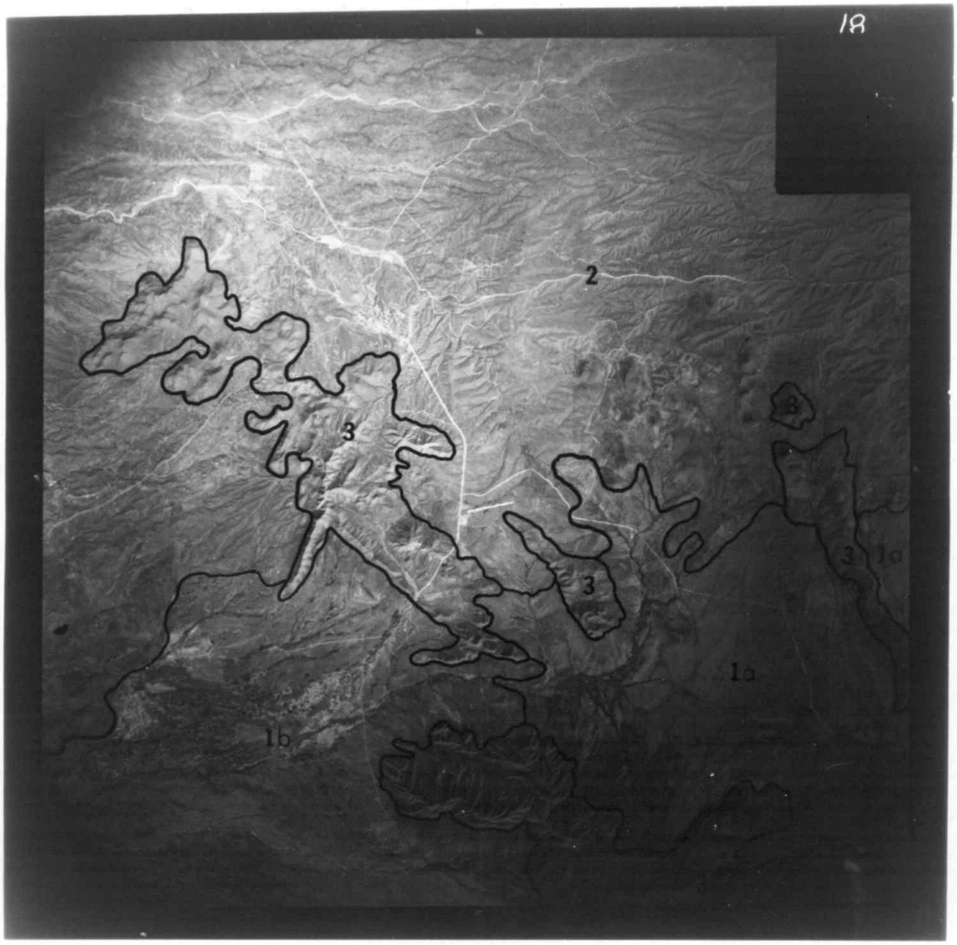

Figure 2. The aerial photograph for this figure was obtained in October, 1968, by the U.S. Geological Survey. It is reproduced here at an average scale of 1:222, 400. Four physiographic classes are delineated within the study area. Those classes are: 1a, flat, smooth lands; 1b, flat slightly dissected lands; 2, rolling and moderately dissected lands; and 3, hilly lands. A brief discussion of the associated physiographic, geology, and soil of the study area is presented on the following pages.

a. A clay loam, Guest series (Torrifluvent Haplustoll), Mollisol

b. A loam, McClellan series (Typic Torrifluvent), Entisol

c. A gravelly to cobbly sandy loam, Continental series (Typic Haplargid), Aridisol

d. A gravelly sandy loam, Cove series (Typic Paleorthid), Aridisol

e. A loamy, Gila suite[1] (Typic Torrifluvent), Entisol

The first two series, Guest and McClellan, have been reported to occur in the Tobosa Bottoms at the Walnut Gulch Experimental Watershed (Gelderman, 1970). The Continental and Cave series dominate the fans, and the Gila suite makes up the soils of the valley floor (Interagency Technical Committee, 1963).

Mapping Unit 1b includes flat, slightly dissected lands which occur in areas of Quaternary gravel, sand, and silt alluvium. The major associated soil is a gravelly loam, Cave series (Typic Paleorthid), Aridisol.

Mapping Unit 2 includes rolling and moderately dissected lands which occur in areas of Tertiary and Quaternary silt, sand, and gravel alluvium. All the major soils associated with this parent material are gravelly loams. One soil, Hathaway series, is (Aridic Calciustoll) a Mollisol. Two others, Bernardino and

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[1] Group of soil series genetically related to the Gila series.

Rillito, are Aridisols (Ustollic Haplargid and Typic Calciorthid, respectively).

Mapping Unit 3 occupies hilly lands of either sedimentary or igenous rocks. The sedimentary hills are a combination of limestone, sandstone, and shale of either Carboniferous, Devonian, Permian, or Cretaceous age. The major soils associated with the Limestone Hills appear to be rocky loams of the Tortugas series (Lithic Haplustoll), Mollisol.

Granite and related intrusive rocks of tertiary age are found on the Tombstone Hills and the hills south of the Dragoon Mountains. The major soils on these hills are a rocky loam, House Mountain series (Lithic Torriorthent), Entisol, and a gravelly sandy loam, Faraway series (Lithic Haplustoll), Mollisol.

A third group of hills consist of Tertiary andesite. The associated soils (at least on the areas being surveyed) are gravelly loams to cobbly or rocky clay loams, Graham series (Aridic Lithic Argiustolls), Mollisols.

No published work other than the above has made clear the possible relationship of geologic features to soil or vegetation in the study area.

Vegetation

The largest portion of the study area is occupied by shrubs where Acacia vernicosa (mescat acacia), Larrea tridentata (creosotebush), Flourensia cernua (tarbush), and Mortonia scabrella (mortonia) are the most prominent species. Grassland with or without shrubs and other species are present in the area. The most important grass species are Bouteloua eriopoda, B. curtipendula, B. hirsuta, B. chondriosioides (grama grasses); Aristida barbata, A. divaricata, A. hamulosa, A. pansa, A. wrightii, A. glauca (three awn); Hilaria mutica (tobosa); and H. belangeri (curly mesquite). The shrubs and other species usually scattered in the grassland are Prosopis juliflora (mesquite), Haplopappus tenuisectus (burroweed), Ephedra trifurca (mormontea), Yucca elata (soaptree yucca), Calliandra eriophylla (false mesquite).

A mixed shrub-grass cover is found in the hills where shrubs occupy the tallest layer and grasses the lower layer. The most common and widely distributed shrub species are Acacia constricta (whitethorn), Fouquieria splendens (ocotillo), and Aloysia wrightii (aloysia). Bouteloua curtipendula (sideoats grama), B. eriopoda (black grama), and Eragrostis intermedia (plains lovegrass) are the most important grasses.

Land Use

Most of the area can be classified as rangeland. The condition of this resource depends upon the potential of the site, past and present use, fire, etc. No production figures were documented in this study, but from observations during field work, it appears that the forage production on the ranges where a considerable amount of shrubs are present fluctuates between zero and a few pounds per acre. In the most productive bottomlands, forage production reaches several hundreds or thousands of pounds per acre reflecting high grazing value.

The prevailing ecological conditions appear to favor the growth of good forage species, mainly grasses, highly suitable for livestock raising. This activity has provided livelihood for many people in this area as well as in the state. A brief résumé on the history of the livestock industry is relevant to present range condition and problems.

Wagoner (1952) provides some information on development of the livestock industry in southern Arizona. He points out that the activity has two periods, (1) the Spanish which dates back as early as 1540, and (2) the Anglo-American which began as a result of the Southern Pacific Railroad. The Spanish period was subject to Indian harassment and could never become an established enterprise. The Anglo-American period became an established enterprise by the 1880's. It was highly favored by the completion of the railroad which facilitated the transportation of the livestock to market. At that time, the main concern of cattlemen was maintaining a large number of cattle. By the middle of the 1880's, the ranges of southern Arizona were overstocked. This situation plus the drought which started in 1891 and lasted for several years began a serious deterioration of the range.

Thornber (1910) describes the southwestern ranges as having a "wealth of plant growth" practically everywhere in the country, prior to the time large herds had begun to graze on it.

Gilluly (1956) states that grama grasses stood stirrup high over most of the Sulfur Spring Valley and Government Draw before the advent of the great herd in the 1880's. Likewise, the increase of shrubs in the environs of Tombstone is believed to have been caused by the varying intensities of grazing since the settlement of the town in 1879 (Gelderman, 1970).

Other important land uses of the area include mining, watershed, and residential development. Mining has been of great importance on the area since the settlers arrived in the early 1880's. This activity was concentrated in the Tombstone Hills although one may find prospect mining pits generally throughout the area. Mining reached its peak in the early 1880's remaining as an important activity until the first decade of this century. At the present time, few if any mines are in operation.

The area dominated by Mortonia scabrella appears to have a great potential for watershed purposes. In the last five or ten years, housing projects have been developed on the east, north, and southwest outskirts of Tombstone.

REVIEW OF LITERATURE

Phytosociology

Phytosociology is the science of vegetation. It deals with the study of all characteristics of plant communities, i. e., their physiognomy, floristic composition, community morphology and structure, or characterization, description, and classification; community development and change; the multilateral relations and interactions of plants with one another and with their environment; and the geographic distribution of communities (Becking, 1957).

For the several approaches to the study of vegetation which have been proposed, the reader is referred to Whittaker (1962) who provides an excellent review of the classification of natural communities, and to Becking (1957) who describes the general history of European phytosociology with emphasis on the Zurich-Montpellier school. The latter will be discussed in the present work.

The Zurich-Montpellier school of phytosociology has not appealed to Anglo-American ecologists as it has to Europeans and those in other parts of the world. The main reason has been the lack of understanding of the basic concepts upon which the science and applications rest as conceived by one of its major proponents, Braun-Blanquet. However, Moore (1962, p. 767) referring to Anglo-American ecologists says, "there is developing desire to understand

and learn." Literature about vegetation studies where the Zurich-Montpellier approach is used in the United States is difficult to find.

Poulton and Tisdale (1961), Poulton (1962, 1967) have consistently emphasized the importance of phytosociological concepts in the analysis of the resources of naturally vegetated areas. Whittaker (1962, p. 135) and Egler (1954) recognized the advantages of the approach. Both authors agree on the main contributions of the Zurich-Montpellier approach to the study of vegetation. Their ideas can be summarized by Whittaker as follows:

> Some of the most impressive successes of the system are in the area of applied phytosociology. In English-language ecology, no real equivalent of the extensive and effective phytosociological work in vegetation mapping, site indication, and land management exists.

Prior Vegetational Investigations

No work of the kind that I am presenting in this research has been accomplished on my study area or in areas adjacent to it. However, several publications having general information about the vegetation of the area have been published, the most complete being:

Author	Vegetation Descriptor
Shreve (1917)	Desert-grassland transition
Shantz and Zon (1924)	Mesquite grass (Desert grassland) Creosote bush (southern desert shrub)

Author	Vegetation Descriptor
Küchler (1964)	Creosote bush-tarbush (*Larrea-Flourensia*) Grama-tobosa shrubsteppe (*Bouteloua-Hilaria-Larrea*)
Aldous and Shantz (1924)	Region 8 (comprising 14 vegetation types, most of them covered by grasses)
Shreve (1942)	Desert grassland transition
Nichol (1952)	Desert grass (mesquite)
Humphrey (1963)	Southern desert scrub Grassland
The Interagency Technical Committee Report (1963)	Chihuahuan desert shrub
Darrow (1944)	Mesquite, creosote bush, desert shrub, desert shrub-grassland, chaparral and mountain browse
Agricultural Research Service (1967)	Brush Whitethorn, creosotebush and tarbush Mortonia, whitethorn, and creosotebush Oak woodland Grassland Black grama, curly mesquite Black grama, blue grama Tobosa grass, sideoats grama Tobosa grass (swale)

The information contained in these reports was not in accordance with the objectives of the study. They were done on very different premises such as physiognomy, dominance, stage of succession (i. e., natural, potential versus actual vegetation), degree of detail, and validity of the information in view of present land management problems.

The Fidelity Concept

The basic premises upon which the Zurich-Montpellier approach rests have been fully described by Becking (1957) and Moore (1962). Only those which are relevant to the present study are being highlighted. The proper place to start is with the understanding and meaning of "fidelity" and its derivations, i.e., degrees of fidelity and character species. The concept was firmly attached to the association concept at the Amsterdam Botanical Congress in 1935 (Schallig, 1967). Fidelity is based upon the strong preference of certain species for particular kinds of environments (Becking, 1957). Becking contends that such species growing in specific environments are of great diagnostic value for the characterization of a community and they are called "character species."

The groups of faithful species as determined from the data analysis help to identify the associations. They are useful labels or identification aids for an association which has already been determined by application of classification techniques to the complete complement of species occurring more or less regularly in different stands (Moore, 1962).

Five degrees of fidelity have been presented in the literature:

(1) exclusives (fidelity class V) are those species restricted exclusively to certain vegetation units; (2) selectives (fidelity class IV) are species having a strong preference for one vegetation unit, but also occurring rarely in other units; (3) preferents (fidelity class III) are species occurring in other vegetation units but they reach their optimum distribution in one vegetation unit. This concept is also applied to a species with equal presence in two communities but with a significantly higher cover and vitality in one community than in the other (Becking, 1957); (4) indifferents (fidelity class II) do not have any particular preference for any vegetation unit; and (5) strangers (fidelity class I) are species which rarely occur in the vegetation unit.

The concept of fidelity should not be confused with presence or constancy. Presence is determined from stand observations as percentage of occurrence in several stands representing the same plant community. Constancy is similarly determined from observations in a constant size plot.

High constancy species are not necessarily restricted to one kind of plant community and may be dominant or sparsely distributed within the stand. Faithful species, on the contrary, may be non-dominant and have a restricted distribution. Moore (1962, p. 762) tries to establish some relationship between fidelity and constancy:

> . . . far greater importance and more significance is given to fidelity than to purely quantitative characteristics especially when fidelity is combined with high constancy.

Becking (1957, p. 445) points out:

> On pioneer communities faithful species will usually be a prominent and constant species. However, in well developed communities with complex stratification, character species are inconspicuous and often rare. Only character species of vegetation units of highest classificatory rank (order, class) are the most common and often locally dominant species.

In my study the character species not of order or class but rather of alliances were found to be the most prominent, and have the highest presence.

Poore (1955b, 1956) has criticized the lack of appreciation by the continental phytosociologists of the importance of dominant and more common species, both in determining the structure of the community and in establishing relationships. He and others have also criticized the over-emphasis of fidelity as a characteristic of the association but in spite of criticism it is a valid and useful concept.

The Association Concept

Another important concept of the Zurich-Montpellier school of phytosociology is its basic unit of classification--the association. The Third International Botanical Congress, held in Brussels in 1910, defined the concept of association as a unit which is floristically, ecologically, and physiognomically homogeneous. An association is characterized not merely floristically but also ecologically, dynamically, and geographically (Moore, 1962). It was not until 1935 when

The International Congress of Amsterdam unanimously reserved the term specifically for the vegetation units identifiable by character and differential species. It should be remembered, though, that the association as such is an abstraction--it is the result of the tabularization or analysis and grouping of floristically homogeneous stands corresponding closely to one another.

Such tabulation can be done following the classical procedures as outlined by Ellenberg (1956) or by the use of computer programs as suggested by Moore et al. (1970), Ceska and Roemer (1971), and Pyott (1972) which perform the same task as the hand sorting followed in the classical approach but having the following advantages: increase in efficiency, objectivity, and capacity.

As an outgrowth of the association concept, this approach provides for a well defined hierarchy with the class group [the ultimate classificatory possibility in a system having a floristic basis (Westhoff, 1967)] at the top and the facies [an often more or less accidental species combination within an association or subassociation (Braun-Blanquet, 1964)] at the bottom. This facilitates the description of the units in a way which no other approach offers.

My own assessment of the values of the phytosociological approach to study vegetation is as follows:

1. It permits organization into an hierarchy of the classification units.

2. It is suitable both for survey-type vegetation studies where the prime concern is to develop an idea of the major vegetation components and to highly detailed studies.
3. It can be directly related to land and resource management problems.
4. It is easily adapted to computerization.
5. Its hierarchical units may be adaptable to remote sensing techniques--different scales of photography, etc.

The above reasons led me to the conclusion that this approach is the best choice in accomplishing the objectives of my study.

Numerical Taxonomy

Sneath and Sokal (1962, p. 856) define numerical taxonomy as, "The numerical evaluation of the affinity or similarity between taxonomic units and the ordering of these units into taxa on the basis of their affinities." They claim that repeatability and objectivity are the primary aims of numerical taxonomy. A complete treatment of the subject is given by Sokal and Michener (1958), Sokal (1963), Sneath and Sokal (1962), Sokal and Sneath (1963), Rohlf and Sokal (1965), and Williams and Dale (1965). However, its applications to classification were established by Greig-Smith (1964) and Lambert and Dale (1964). Williams and Dale (1965) provide an insight to the concepts and theories of all the approaches presented by Greig-Smith (1964) and Lambert and Dale (1964).

Williams (1967) provides an excellent paper about classifications, how a computer can produce classifications given as he puts it (p. 381), "a taxonometric jargon, a similarity coefficient, and a sorting strategy." He emphasizes the judgment that should be exerted after a computer classification is completed. This article seems to be appropriate in view of the interrelationships that I am dealing with in the present study.

One of the basic hypotheses of the present study is the presence of repeated, discrete stands of vegetation on the area where the work was carried out. How sharp or well defined they are remains to be seen.

All classification schemes may be characterized as hierarchical and non-hierarchical. The former seeks to find the most efficient step at each stage in the progressive subdivision or synthesis of the population. The latter are concerned with finding groups whose members are in accordance with some predetermined measure of likeness (Lance and Williams, 1966a).

Williams, Lambert and Lance (1966, p. 428) point out two independent choices of hierarchical methods of classifying elements into sets.

> First, the strategy may be divisive in that the population is progressively subdivided into groups of diminishing size, or agglomerative, in that individuals are progressively fused into groups of increasing size until the entire population is synthesized. Secondly, the strategy may be monothetic, every group at every stage (except the entire population)

being definable by the presence or lack of specified attributes, or polythetic, the groups are being defined by their general overall similarity of attribute structure.

Out of the four possible combinations outlined by the authors, two of them (divisive-monothetic and agglomerative-polythetic) have some practical applications. The drawbacks of the former have been summarized by Pyott (1972) as follows.

1. The Braun-Blanquet system is agglomerative in that the stand groups are built up on the basis of overall similarity among stands. Characteristic species cannot be used as specified characteristics because they are defined as part of the classification process.
2. A group of stands is determined by at least one species which occurs in every stand of that group and nowhere else. This would be ideal but the reports indicate that this fact is an impossibility.
3. They do not allow consideration for quantitative data but are based entirely on presence and absence.

Regardless of which classification scheme is selected--hierarchical or non-hierarchical--the use of one or the other involves two choices. First, the measure of group density or inter-likeness. This relates to the measure of similarity between species or stands. Second, the chosen measure has to be incorporated into a "sorting strategy" whereby the groups of elements are extracted (Lance and

Williams, 1967). Both are closely related but a separate treatment will be given as a matter of convenience.

Several coefficients of similarity or affinity have been proposed: the coefficient of association (Sokal, 1963; Sokal and Sneath, 1963), matching coefficients (Sokal and Michener, 1958), or non-metric coefficient (Lance and Williams, 1966a; Williams, Lambert and Lance, 1966). These coefficients are based in their simplest form on a 2 x 2 contingency table calculated from the data.

Another coefficient of similarity is based on Pearson's product moment correlation coefficient (Sokal and Michener, 1958; Sokal, 1963; Sokal and Sneath, 1963; Rohlf and Sokal, 1965; Lance and Williams, 1966a; Williams, Lambert and Lance, 1966).

Another coefficient of similarity is the Squared Euclidean distance

$$d_{ij}^2 = \sum_{h=1}^{n} (x_{hi} - x_{hj})^2$$

(Sokal, 1961, 1963; Sokal and Sneath, 1963; Rohlf and Sokal, 1965) in n-dimensional space whose coordinates are the characters (Lance and Williams, 1966a; Williams, Lambert and Lance, 1966) in which qualitative data are accommodated by taking the j^{th} coordinate for an individual as 1 if it possesses the attribute considered, and 0 if it lacks it; or a variant of the above called standardized squared Euclidean distance in which the attributes are standardized to zero mean and unit variance (Williams, Lambert and Lance, 1966).

Distance as a measure of similarity has been widely used apparently because of its compatibility with all the sorting strategies and its ease of calculation by an extension of the Pythagorean Theorem to an n-dimensional space (Rohlf and Sokal, 1965).

Recently, Lance and Williams (1966a) have introduced information statistics as a measure of similarity which appear to have much potential in ecological work; however, it has the disadvantage of being restricted to qualitative data.

As far as the selection of the fusion strategy is concerned, Sokal and Michener (1958) used the pair group method[2] and the weighted group method[3] to determine group structure. Lance and Williams (1966b, p. 218) state that,

> . . . agglomerative hierarchical methods of computer classification all begin by calculating distance-measures to a sorting strategy which depends essentially on the definition of a distance-measure between groups of elements.

Five sorting strategies are mentioned: nearest neighbor[4], furthest

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[2] Only one new member for each group is admited at a given hierarchical level, thus obtaining a diagram of relationships consisting of bifurcations only.

[3] The weighting of new members as equal to the total sum of all old group members.

[4] Defined as the distance between the closest pair of elements, one in each group.

neighbor[5], group average[6], centroid[7], and median[8]. All of these have been worked out from the following classification function:

$$d_{hk} = \alpha_i d_{hi} + \alpha_j d_{hj} + \beta d_{ij} + \gamma \left| d_{hi} - d_{hj} \right|$$

The reports in the literature indicate that most of the similarity coefficients and sorting strategies have been worked out independently. This may create problems as pointed out by Lance and Williams (1967, p. 373), "since the strategy may be restricted by the measure, the latter should be chosen first." Only in a few instances have one or more similarity coefficients been tested along with two or more sorting strategies (Sokal and Michener, 1958; Sokal and Sneath, 1963). The best treatment of these relationships is found in Williams, Lambert and Lance (1966).

Ward (1963, p. 243) describes a procedure "to form hierarchical groups of mutually exclusive subsets on the basis of their similarity with respect to specified characteristics." From a given number of units his method allows their reduction to n-1 mutually exclusive

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[5]The most remote pair of elements.

[6]The distance is defined as the mean of all between group inter-element distances.

[7]Centroid sorting is the distance between group centroids (mean vectors) defined by a conventional Euclidean model.

[8]Group (k) resulting from the fusion of element (i) and (j), located at the midpoint of the shortest side of the triangle defined by (i), (j) and (h), with a distance (d_{hk}), lying along the median of this triangle.

subunits by considering the union of all possible n (n-1)/2 pairs that can be formed and accepting the union with which an optimal value of the objective function is associated. Minimization of the within group sum of squares through the use of Ward's method is achieved. Because of the usefulness of Ward's method for classification purposes, the increasing use of numerical methods in biology, and the availability of a general classification function proposed by Lance and Williams (1967), Wishart (1969) worked Ward's method into Lance and Williams' general function thus adding a sixth sorting strategy.

In regards to Ward's method as a sorting strategy, the only report to my knowledge where it has been used with more than one similarity coefficient is in Pyott's dissertation (1972, p. 34). His evaluation of it is as follows: "It is a space dilating strategy (sensu Lance and Williams, 1967) which is advantageous in the sense that the clusters are more sharply defined."

In addition to similarity coefficients and sorting strategy another important consideration is the kind of data used, that is, presence or absence, quantitative data, and standardized quantitative data. There is agreement among some authors(Harberd, 1962; van Groenewoud, 1965; Pyott, 1967; Moore <u>et al.</u>, 1970) that for a preliminary survey, presence and absence data provides the most effective means of studying vegetation.

Others such as Greig-Smith (1964), Austin and Greig-Smith

(1968) believe that the use of qualitative data does not provide satisfactory results. Thus, the former (p. 153) claims "classification of stands on the basis of presence and absence of species tends to give either too broad or too narrow a classification for practical purposes." The latter (p. 84) point out that "the use of qualitative data removes the concentration of species and the choice of the most frequent species removes the random correlation of rare species."

The situation is not much different while dealing with quantitative or standardized quantitative data although the reports favor the latter.

Sokal and Michener (1958, p. 3) mention the "desirability of the standardization of characters when variability exceed some desirable bounds." Lambert and Dale (1964, p. 72) contend that "if the values are not standardized in some way, the more variable species would tend to deminate the analysis and information of value may be lost." Orloci (1967) suggested and used standardization to remove the effect of stand productivity on interstand Euclidean distance. However, Rohlf and Sokal (1965, p. 3) using two coefficients of similarity, correlation and distance, report "that the effects of standardization of characters is slight upon a distance coefficient."

As can be appreciated, the opinions are different from one author to the other and in some cases (Lambert and Dale, 1964; Austin and Greig-Smith, 1968) contradictory statements can be found in the same article. Rather than helping, this creates more confusion in the reader, but serves to illustrate the state of affairs of the numerical classification subject matter.

As far as the measure of similarity and the sorting strategy used in the present study are concerned, and whether presence and absence or standardized cover values were used to determine those parameters, the following can be said.

The sorting strategy, Ward's method (using squared Euclidean distance as the measure of similarity) was developed on the basis of standardized data. It is weighted toward species having the greatest variance (Wishart, 1969). It is therefore recommended that the sample coordinates be transformed to standard form (zero mean and unit variance) prior to the analysis. Euclidean distance, itself, is weighted in favor of characteristics with large variance (Pyott, 1972), therefore, standardization of the data may be required whenever this measure of similarity is used.

After all the exploratory work by Pyott (1972) where considerations were given to: (1) the two choices of the hierarchical classification (i. e., the monothetic-divisive and the polythetic-agglomerative), (2) actual experimentation using five different vegetation types, (3) two kinds of data (presence and absence and standardized values), (4) two different sorting strategies (group average and Ward's method), and (5) five similarity coefficients, he found that the Euclidean distance as a measure of similarity and Ward's method as a sorting strategy (in a hierarchical-polythetic-agglomerative classification scheme) are the most applicable to the classification of vegetation by the Braun-Blanquet system. These circumstances and the success of Pyott's application of them led me to use these schemes for the analysis of my data.

PROCEDURES

Field Methods

Previous to any field data gathering, the study area was stratified into 31 broad mapping units based on image similarity by the use of high altitude color photography taken at an average scale of 1:222,400 (Table 1). Within each mapping unit, one or several stand observations were documented. The number of observations taken in each mapping unit was determined by the size of the unit, complexity of the photo image as evidenced by its texture and pattern, and on the ground accessibility.

In following this approach, sample selection was easier and the efficiency of field time was increased. The field work was done during the summers of 1969 and 1970.

Based on photo imagery and ground observations, a uniform[9] area was selected and information concerning vegetation, soil surface characteristics, and physiographic features was documented on a stand basis. A ground photograph of each stand location was taken.

In each sample area, a complete species list was obtained. Prominence ratings, plant cover estimates, and sociability were

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[9] By uniform or homogeneous area of vegetation is meant an area in which the superficially observable variations are small compared to those within other areas in the neighborhood (Hopkins, 1957, p. 451).

Table 1. Number of observations taken in the different delineations made on frame no. 81 of U.S.G.S. photography taken in October, 1968, over the study area at an average scale of 1:222,400.

Mapping unit	Proportion of the study area (%)	Number of observations
1	27.7	52
2	5.4	42
3	2.7	26
4	1.9	12
5	1.7	13
6	4.0	18
7	2.4	14
8	1.0	10
9	2.0	15
10	2.9	24
11	1.4	1
12	7.0	19
13	4.0	5
14	4.9	6
15	2.7	not sampled
16	5.0	17
17	4.6	12
18	3.9	14
19	5.2	49
20	2.0	11
21	2.2	11
22	.4	2
23	.3	3
24	2.2	10
25	.7	5
26[1]	.3	-
27[1]	.2	-
28	.1	not sampled
29	.4	12
30	.7	3
31	.1	1
	100.0	417

[1]Urban areas

recorded following previous work by Poulton (1962).

Soil surface characteristics including color (Munsell hue, value, and chroma), cover estimates of bare soil surface, gravel, stones, rocks, bedrock, percent area nonvegetated, and litter were recorded. For the soil cover estimates, visual aids prepared by Terry and Chilingar (1955) were used to help judge percentages. Physiographic features included in records are landform, macrorelief, slope, exposure, and elevation (Table 2).

The exact ground observations were pin pricked on black and white aerial photos (1:20,000 to 1:62,500 scale). Low oblique photographs were also taken in color from small aircraft on selected sections of the study area. These were also useful in selecting stand locations.

It was decided to develop a standard, non-conflicting set of species symbols or identifiers to be used both in field data recording and data analysis to account for the amount of species (440) found on the study area. The method was based on previous work by Garrison, Skovlin and Poulton (1967). A computer program called "RAMOLA" (Richey, 1971) was developed for us to accomplish this task. The program is quite flexible and allows for additions or deletions to the master file at any time. Also, reports are easily generated in a variety of formats.

The only significant modification to Garrison's work was the

Prominence ratings and cover classes (Poulton, 1962, p. 11-12); sociability classes as cited by Becking (1957, p. 431):

Prominence ratings	Description
5	- Species which dominate the aspect of the layer.
4	- Species which are codominant in the aspect of the layer.
3	- Species which are easily seen by standing in one place and looking casually around.
2	- Species which can be seen only by moving around in the stand or by looking intently while standing in one place.
1	- Species which can be seen only by searching for them in and around other plants.

Cover classes:

Class range (percent)	Class	Midpoint
0+ - 1	1	0.5
1 - 5	2	3.0
5 - 10	3	7.5
10 - 25	4	17.5
25 - 50	5	37.5
50 - 75	6	62.5
75 - 95	7	85.0
95 - 100	8	97.5

Sociability class	
1	- Growing solitary, singly.
2	- Growing in small groups of a few individuals.
3	- Large group of many individuals, small scattered patches.
4	- Patches or a broken mat.
5	- Extensive mat almost completely covering the whole plot area.

Table 2. An example of the kind of information documented at each location sampled.

Ground Truth Location No. 459; Photo Record Card No. 1165; Observer EGM; Date 9-4-69; Location: T20S, R22E, Sec. 32, SW 1/4 of NE 1/4.

VEGETATION

Species	Prominence[1]	Cover[1]	Sociability[1]
2 Acve	4	4	1
2 Latr	4	4	1
2 Flce	3	3	1
2 Krpa	2	2	2
2 Dafo	2	1	1
2 Fosp	1	1	1
3 Ople	1	1	1
5 Mupo	4	4	2
5 Sema	2	2	1
5 Dica	2	1	1
5 Boer	2	1	1
5 Erpu	2	1	2
6 Boar	3	2	1
6 Pahi	3	2	1
6 Arad	2	1	1
6 Chvi	2	1	1
6 Erci	2	1	1
6 Erdi	1	1	1
8 Taau	3	2	1
8 Baab	3	2	1
8 Apun	2	1	1
8 Jama	2	1	1
8 Caba	1	1	1
8 Pewr	1	1	1
8 Sipr	1	1	1
8 Teco	2	1	1
8 Pena	2	1	1
8 Soel	1	1	1
8 Zipu	1	1	1
9 Saab	3	3	2
9 Tila	3	2	1
9 Acne	2	2	1
9 Amfi	2	1	1
9 Euse 2	2	1	1
9 Kagr	1	1	1
9 Boco 1	1	1	1
9 Euex	1	1	1

PHYSIOGRAPHY

Elevation: 4275 ft.

Landform: Interfluve of Alluvial Plain

Slope: 2%   Exposure: NE

Geology: Alluvium

SOIL SURFACE CHARACTERISTICS

	Color: Dry	Color: Wet	Cover[1]
Bare Soil Surface	10YR7/4		6
Gravel	-	-	5
Stones	-	-	1
Non-vegetated Ground cover	-	-	5
Litter	-	-	2

[1] For explanation see facing page.

increase in the number of growth forms to ten instead of four. These growth forms and their numerical codes are: (1) Trees, (2) Shrubs, (3) Cacti, (4) Agaves and related (Engler, 1964), (5) Perennial grasses, (6) Annual grasses, (7) Grasslike, (8) Perennial forbs, (9) Annual forbs, and (10) Cryptogams.

The standard reference used for the proper identification of the botanical name of the plant species found on the study area was Kearney and Peebles (1964). Gould (1951, 1968) and Humphrey (1970) were especially helpful on the grasses, Benson and Darrow (1954) in trees and shrubs, and Benson (1969) in cacti.

Data Analysis

Due to the large amount of information gathered, it was evident that analysis of the data following the classical phytosociological approach (Ellenberg, 1956) of studying vegetation was unrealistic. This situation, plus the development of a series of eight computer programs (STNOS, SPPNOS, RAWTABLE, STDORD, COCALC, HICLAS, DATAREGR, and DANORM[10]), designed to classify vegetation (Pyott, 1972), prompted me to choose the computer approach to vegetation classification which follows essentially the phytosociological concepts of Braun-Blanquet (1964) and Ellenberg (1956).

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[10] For more detailed information on what each program does, the reader is referred to Pyott's doctoral dissertation (1972).

Because of the limitations of the programs (70 stands or observations, and 90 species or attributes), the data were divided into nine sets. The size of the sets ranged from 24 to 69 stands and 38 to 86 species. These sets grossly conform with the general physiognomy of the vegetation as well as with some physiographic and geographic locations within the study area. In addition, a proportionate random sample having 43 stands and 49 species (Table 3) was drawn so that a classification based on the random drawing from all the stands within each set (one drawing per each ten stands) could be compared with the classification derived from the separate analysis of each of the nine sets.

Identifiers for each of the sets and the number of stands per set is given as follows:

CD - Chihuahuan Desert vegetation (dominated by shrubs) - 69

DR - Dragoons (grassland) - 66

BR - Brushland (like CD but having *Yucca baccata* and *Nolina microphylla*) - 60

AH - Andesite Hills - 58

PRS - Proportionate Random Sample (for every ten stands one draw was taken in each set) - 43

MU - Mule Mountain area (like AH but with ocotillo thickets) - 42

GR - Grassland (along Davis road) - 32

Table 3. Original breakdown of the data sets made to carry out the classification.

Data sets[1]	Total no. observations/ set	Total no. stands[2] used in classification	Total no. species/ set	Total no. species[2] remaining after using Program SORT[3]	Total no. species used in classification	Lower presence (%)	Lower presence limit (no. stands)
CD	70	69	167	91	86	8.7	6
DR	66	66	240	99	38	13.6	9
BR	60	60	211	96	65	13.3	8
AH	58	48	243	91	43	13.8	8
PRS	43	37	274	95	49	16.3	7
MU	42	42	238	97	58	14.3	6
GR	42	29	212	98	55	18.8	6
KR	40	40	228	95	74	17.5	7
TH	26	26	222	88	78	19.2	5
LH	24	20	200	94	84	20.8	5

[1] CD= Chihuahuan Desert; DR = Dragoons; BR = Brushland; AH = Andesite Hills; PRS = Proportionate Random Sample, MU = Mule Mountains; GR = Grassland; KR = Kendall Ranch and Tobosa Bottoms; TH = Tombstone Hills, and LH = Limestone Hills.

[2] Seventy stands and 90 species is the capacity of the program (COEFCALC).

[3] This program lists the species numerically by presence, subsequently the species with the lowest presence were erased from the original data file.

KR - Kendall Ranch and Tobosa Bottoms - 40

TH - Tombstone Hills - 26

LH - Limestone Hills - 24

The latter two, TH and LH, were considered as having 30 stands each so that there would be a minimum of three stands per set in the random drawing mentioned above.

Some preliminary work was accomplished in order to use the aforementioned programs. The data of the original records were transferred to an 80-column data form to facilitate the key punching operation. One card per species per stand was keypunched and placed in its respective set. The cards of each set were put into a disk file with the proper label of the set under consideration. The execution of the programs was carried out from a teletype on a CDC 3300 computer. The stands were classified on both presence and absence as well as standardized cover estimates. The measurement of similarity among species and stands using presence and absence was the Euclidean point d-square which in its most simplified form can be reduced to $d^2 = b + c$ in the usual (a, b, c, d) symbolism of a 2 x 2 contingency table (Lance and Williams, 1966a) where b and c represent the unmatched cells of the table. When the stands were classified using standardized cover estimates, the Euclidean squared distance

$$d^2 = \sum_{i=1}^{p} (X_{il} - X_{im})^2$$

when dealing with a p dimensional space (p = number of species considered for stand classification, Pyott, 1972) was used as the measure of similarity. The sorting strategy used for both the species and stands was the Ward's method as described by Wishart (1969). He worked this strategy into the linear function described by Lance and Williams (1966a, 1967).

$$d_{hk} = \alpha_i d_{hi} + \alpha_j d_{hj} + \beta d_{ij} + \gamma \mid d_{hi} - d_{hj} \mid$$

which has been used to compute relationships after fusion of clusters for five sorting strategies where

d_{hk} = distance to be found between the group k (resulting from the fusion of cluster i and j) and group h.

d_{ij} = intergroup distance between group i and j.

d_{hi} = intergroup distance between group h and i.

d_{hj} = intergroup distance between group h and j.

The parameters α_i, α_j, β and γ in the Ward's method are calculated as follows

$$\alpha_i = \frac{n_h + n_i}{n_h + n_k} \; ; \quad \alpha_j = \frac{n_h + n_j}{n_h + n_k} \; ; \; \beta = - \frac{n_h}{n_h + n_k} \; ; \quad \gamma = 0$$

where n_h, n_i, n_j = number of elements in the h^{th}, i^{th} and j^{th} cluster.

$$n_k = n_i + n_j$$

A series of changes in the number of species takes place to meet the specifications of the programs. Such changes are rather dramatic in going from the original number of species to the number left over after the data are sorted. By the use of SORT program (Sullivan, 1968), the species are listed alphabetically by symbol and numerically by their presence. Those species with lowest presence are removed from the file to comply with the operational limitations of the programs. This explains the drastic reduction of the number of species from column 4 to column 5 on Table 3. A second reduction takes place when the coefficient matrix is calculated (program COEFCALC). This is done by setting up a lower presence limit: COEFCALC has a capacity of 90 species and 70 stands. The final reduction to reach the number of species used in classification is obtained when the data are rearranged following classification (program DAREGR). At this point, the lower presence limit used previously plus a proportion of the maximum distance value of the last iteration in the classification process and lower limit of the presence of species needed to form a species cluster is specified in Table 4. It should be mentioned that the deleted species between the fifth and sixth columns of Table 3 are not dropped completely but are only temporarily set aside and are added to the foot of the table at the end of the classification output.

The general classification scheme selected is a hierarchical polythetic-agglomerative one because such a scheme is most applicable

Table 4. Constraints used for classification in relation to distance and number of species or stands in each data set.

Data set[1]	Proportion of maximum distance used for classification			Minimum no. species or stands required to form cluster
		stands		
	species	presence or absence	standardized data	
CD	.04	.21	.80	2
DR	.04	.08	.13	2
BR	.03	.15	.60	2
AH	.07	.15	.70	2
PRS	.05	.15	.45	2
MU	.04	.10	.50	2
GR	.04	.15	.30	2
KR	.05	.13	.20	2
TH	.05	.30	.60	2
LH	.05	.20	.40	2

[1]CD = Chihuahuan Desert; DR = Dragoons; BR = Brushland; AH = Andesite Hills; PRS = Proportionate Random Sample; MU = Mule Mountains; GR = Grassland; KR = Kendall Ranch and Tobosa Bottoms; TH = Tombstone Hills; LH = Limestone Hills

to the classification of vegetation by the Braun-Blanquet system (Pyott, 1972).

The printouts resulting from the classification schemes were examined carefully. The fundamental unit of vegetation classification--association--was identified from the classification outputs by the application of the fidelity concept. Three fidelity classes, exclusives (fidelity class V), selectives (fidelity class IV), and preferentials (fidelity class III) were utilized. Species within these fidelity classes were considered as character species for the association since to a certain degree they tend to occur or be restricted to an environment. Quite often, in this study, the concept of preferential character species (Becking, 1957) was useful in cases where a species did show a definitive preference for a certain environment as evidenced by a higher cover and vitality, even though it was found in other areas.

The upper and lower rank of the association was also determined. In the former, one or a few data sets were pooled together to find the character species for the new unit. The procedure for determination of the character species of this rank was similar to that used for the determination of the character species for the association. In the latter the differential species were utilized to separate subassociations within associations and alliances.

A species was considered as differential if it occurred in more than 50 percent of the stands included in a subassociation and completely absent in other subassociation(s), or having 75 percent presence or greater in a subassociation and less than or equal to 25 percent in other subassociation(s). Cover value and vitality were also considered. It should be remembered, however, that a species can be differential in different associations.

Two criteria were used to evaluate the results of the classification schemes of both the presence and absence and standardized cover estimates. The first refers to the graphic representation of each classification scheme through a dendrogram[11] and the second was the observation of the internal pattern of each potential unit. Other criteria that appear in the literature such as well defined and ecologically meaningful groups (Williams, Lambert and Lance, 1966) were used to a degree.

Once the classification was achieved and the units identified, one step further was accomplished. This step was to test the differentiating value of the character and differential species which characterize or identify a given unit. Stepwise discriminant analysis, BMD07M (Sampson, 1968), including canonical analysis (Seal, 1966) adapted and modified to the capabilities of the O. S. U. Computer Center was utilized.

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[11] Dendrograms are tree-like schemes which indicate the affinity of taxa to their nearest relatives (on the basis of similarity or phenetic resemblance alone, without any necessary phytogenetic implications) (Sokal and Rohlf, 1962).

The classification outputs from presence and absence and standardized data were transposed (using the program called DATRNPS) from a species by stands array into a stands by species array (Pyott, 1972) and saved under a distinct file label. This operation is a requirement for the stepwise discriminant analysis to work. Not all the species (attributes) that were meaningful to the classification of each set were included since the program handles only 41 species. Only species that appeared to be differential for a specific set were chosen and only in a few instances were ubiquitous species selected.

Each data set was divided twice into groups and subgroups. Each division represented a hierarchical level. Two runs per set per level were carried out. At the first run the 41 species were entered in the process and a classification matrix was printed at specified steps, i.e., 3, 6, 12, 18, 24, 30, 36, and 41. This gives an idea of how many steps are needed on the second run (subproblem) to achieve a perfect discrimination.

The subproblem was run as was the problem with the exception that the classification matrices were printed only at those steps previous to the one having the perfect discrimination. Proceeding in this way the step at which the perfect discrimination was achieved is pinpointed, i.e., if in the first run the perfect discrimination appears between steps 19-24, in the second run the printing of the matrix should be specified to appear at steps 19, 20, 21, 22, 23, and 24; step 18 is not included since in the first run this matrix appeared with an imperfect classification.

The information of the stepwise discriminant analysis relevant to the present study is the number of species (attributes) required to achieve a perfect discrimination, the F values of the group and subgroup means to test the significance among or between them in a pairwise manner, the amount of total dispersion accounted for by the first and second canonical variables, the plotting of the first against the second canonical variable to see how well the groups were separated, and the within groups dispersion.

This study was carried out in a very restricted area, therefore, the validity of this suggested classification will have to come from a broader, regional study of the environs which are vegetationally similar. The strength of the interpretation of these associations will be greater as they are found to hold up throughout a more extensive region. On the other hand, if a given unit is labeled as a subassociation instead of an association (given the amount of information on hand) and subsequently another person demonstrates with data from a more extensive area within the same region that such a unit is an association, then a desirable modification of the proposed hierarchy will be in order.

To solve these kinds of problems, Ellenberg (1956) proposed an elevation of the rank levels--association to alliance, this to order, and finally to classes. Braun-Blanquet (1964) has added "class group" as the highest unit in the hierarchy.

The above considerations are important when one realizes that the location of part of the study area lies on the fringe of the Chihuahuan Desert or in an area that has affinities to the Chihuahuan Desert. Therefore, I would expect the community relationships to be more apparent as one moves both to the north and particularly to the south along the San Pedro River and especially to the southeast into more typical Chihuahuan Desert.

To aid use and application of these results a dichotomous key for the recognition of alliances and associations has been prepared from the analytical data and classification results (Appendix Table 3).

RESULTS AND DISCUSSION

As indicated before, the amount of information collected for the present study was enormous. An effort was made to synthesize as much meaningful information as possible in meeting the outlined objectives. Only species that have value in the identification of alliance, association, and subassociation were included. Companions (fidelity class II), strangers (fidelity class I), and some of the most ubiquitous species were left out.

This determination of the fundamental unit of vegetation (plant associations), as well as its subassociations and its higher hierarchical grouping (alliances) is the first time such an hierarchical classification has been presented for desert vegetation in North America. This approach is important to the interpretation of multi-stage, remote sensing imagery where the mapping units can be composed of a single taxonomic unit (alliance) or several forming complexes. In the latter case, it depends upon whether one is talking about space or high flight imagery. At large scale there may be some justification for delineating mapping units which represent a single taxonomic unit (subassociation) which is presumed, then, to be more specifically indicative of unique environmental features whether one is mapping or simply describing the vegetation units on an area with no previous phytosociological information. The proposed units are in Schallig's terms

(1967, p. 24), ". . .a rapid, to be true, coarsely outlined survey of the plant cover of the study area" or as Moore (1962, p. 764) has commented, the results obtained by the continental phytosociologists are ". . .merely working hypotheses to be tested by further work." Before going into the discussion of each of the vegetational classes obtained from the study a summary is presented in Table 5. The idea behind this table is to provide the reader with a view of how the original data sets entered in the analysis and their subsequent assignment to the respective classes. In addition, the table introduces the groups that will be discussed later on and shows their interrelationships.

Alliance I (*Acacia vernicosa*-*Larrea tridentata*-*Flourensia cernua*)

The stands of Alliance I occupy the largest portion of the study area. Microphyllous shrubs dominate the landscape; other growth forms are scattered throughout without any definite pattern. The tall shrub layer is represented by three shrubs, *Acacia vernicosa* (mescat acacia), *Larrea tridentata* (creosote bush), and *Flourensia cernua* (tarbrush). The prominence of any one of these shrubs in a specific stand of Alliance I seems to be determined by local environmental conditions.

The lower shrub layer is generally composed of such species as

Table 5. Illustration of the way the original data sets were broken down as the result of the classification.

Original data sets	No. of stands in original data sets	Size of new group	Proposed associations	Higher rank unit
CD[1]	69	49	Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri)	Alliance I (Acacia vernicosa-Larrea tridentata Flourensia cernua)
		20 (from CD)	Association B (Rhus microphylla-Dalea formosa)	
BR	60	49		
		11	Association C (Gutierrezia sarothrae/Eriogonum abertianum	Alliance II (Yucca elata/Bouteloua eriopoda)
		22 (from DR)	Association D (Menodora scabra/Tridens grandiflorus)	
DR	66	16 (from KR)		
		44 (from DR)	Association E (Hilaria belangeri)	
KR	40	12		
		19 (from GR)	Association F (Gilla rigidula-Rhynchosia texana)	
GR	32	12 (from KR)	Association G (Hilaria mutica/Eriochloa gracilis/ Crotalaria pumila)	
		13 (from GR)	Association H (Haplopappus tenuisectus/Eragrostis lehmanniana)	
		13 (from MU)		
MU	42	5	Variant (1a)	Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii)
		11	Association I (Ayenia pusilla/ Eragrostis intermedia)	
		13		
TH	26	26	Association J (Cnidoscolus angustidens)	
AH	58	30[2]	Association K (Typical association)	
		14	Association L (Agave palmeri-Agave parryi/ Haplopappus laricifolius)	
		14		

(Continued on next page)

Table 5. (Continued).

Original data sets	No. of stands in original data sets	Size of new group	Proposed associations	Higher rank unit
LH	24	24	Association M (<u>Mortonia scabrella</u>)	
PRS	43	14		Alliance I
		13		Alliance II
		10		Alliance III

[1]CD = Chihuahuan Desert; BR = Brushland; DR = Dragoons; KR = Kendall Ranch and Tobosa Bottoms; GR = Grassland; MU = Mule Mountains; TH = Tombstone Hills; AH = Andesite Hills; LH = Limestone Hills; PRS = Proportionate Random Sample.

[2]In this unit ten stands were eliminated because they did not meet the operational specifications, even though they corresponded to the typical association.

Parthenium incanum (mariola) and Krameria parvifolia (ratany). In some instances, the former becomes as important, coverwise, as the tall shrub layer. The herb layer is represented by a few grass species such as Muhlenbergia porteri (bush muhly) near or in the protection of bushes. In the interspaces Erioneuron pulchellum (fluffgrass) is the most common species. Zinnia pumila (zinnia), Bahia absinthifolia (bahia) and Euphorbia spp. (spurge) are the commonly occurring forbs.

Four additional features are important in this unit. (1) The presence of Condalia spathulata (Mexican crujillo) scattered on the uplands. (2) The presence of inclusions of Association G (Hilaria mutica/Eriochloa gracilis/Crotalaria pumila) on the parallel drainageways; Prosopis juliflora (mesquite) and other shrubs are scattered in these inclusions. (3) The vegetation along the washes and in the alluvial terraces is composed mainly of Prosopis juliflora (mesquite), Chilopsis linearis (desert willow), and Hymenoclea monogyra (burrobrush) in the former; Prosopis juliflora (mesquite), Haplopappus tenuisectus (burroweed), Aristida adscencionis (six-weeks three awn), Bouteloua barbata (six-weeks grama), B. aristidoides (needle grama), and Proboscidea arenaria (unicorn plant) among others are present on the latter. (4) The character species for the alliance are also the most prominent species. This is not uncommon for higher rank units (Becking, 1957). The proposed character species of the alliance and the association as well as the differential species of the subassociation are presented in Table 6.

Table 6. Alliance I (Acacia vernicosa-Larrea tridentata-Flourencia cernua).

	Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri)						Association B (Rhus microphylla-Dalea formosa)									
Group	1A		1B		1C		2D		2E		2F		2G		2H	
No. stands/group	18		15		16		20		10		14		10		15	
Mean no. species/group	39.7		34.6		29.6		27.2		35.0		45.1		26.8		39.0	
	% P[1]	MCE[2]	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed character species of the alliance																
2 Acve	100.0	23.2	100.0	13.7	93.0	8.3	100.0	17.0	100.0	25.0	100.0	23.7	90.0	12.7	100.0	15.9
2 Latr	100.0	13.3	100.0	9.9	93.0	11.2	95.0	14.5	100.0	7.2	93.0	8.1	90.0	6.6	93.0	7.7
2 Flce	100.0	9.0	100.0	9.7	100.0	8.5	95.0	8.4	70.0	1.8	64.0	4.1	80.0	5.3	67.0	2.4
5 Mupo	94.0	3.9	100.0	6.7	94.0	7.8	100.0	8.9	100.0	6.8	100.0	7.3	80.0	8.2	87.0	1.1
8 Zipu	94.0	2.7	100.0	4.9	67.0	1.8	95.0	6.2	100.0	8.8	100.0	7.5	80.0	2.6	93.0	10.0
5 Erpu	78.0	1.2	100.0	3.9	63.0	1.7	90.0	4.4	100.0	4.3	100.0	5.6	90.0	2.0	93.0	3.9
Proposed character species of Association A																
6 Pahi	50.0	.6	87.0	.9	56.0	.6	45.0	.5	10.0	.1	29.0	.3	10.0	.1	40.0	.4
9 Tila	78.0	.9	93.0	1.5	69.0	1.1	35.0	.5	30.0	.3	29.0	.3	10.0	.1		
9 Boco 1	83.0	.8	93.0	1.2	50.0	.6	45.0	.5	20.0	.2	7.0	.1			20.0	.2
Proposed character species of Association B																
2 Rhmi	22.0	.3	47.0	.7	38.0	3.6	95.0	2.2	70.0	4.5	93.0	6.2	80.0	2.1	87.0	5.4
2 Dafo			7.0	.1	25.0	.3	65.0	.7	100.0	1.2	100.0	2.1	30.0	.3	93.0	1.8
Proposed differential species of Subassociation 1A																
9 Eumi	50.0	.6	7.0	.1	13.0	.1										
Proposed differential species of Subassociation 1B																
9 Euse	11.0	.2	80.0	.9			15.0	.2								

(Continued on next page)

Table 6. (Continued).

	Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri)						Association B (Rhus microphylla-Dalea formosa)									
	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed differential species of Subassociation 1C																
5 Scbr	6.0	.6			56.0	.8	5.0	.1								
1 Prju	39.0	.4	7.0	.1	80.0	2.5	25.0	.3	10.0	.1	14.0	.1	20.0	.4	20.0	.2
Proposed differential species of Subassociation 2E																
5 Ardi									90.0	1.1					13.0	.1
5 Arpu 1									90.0	1.5					27.0	.5
Proposed differential species of Subassociation 2F																
8 Abin					6.0	.1	30.0	.3			71.0	.7			7.0	.1
Proposed differential species of Subassociation 2G																
9 Euse 1	6.0	.5	7.0	.1	50.0	.8	15.0	.2	10.0	.1	7.0	.1	50.0	.9		
Proposed differential species of Subassociation 2H																
4 Dawh									20.0	.2	29.0	.3			73.0	1.0
8 Thte			7.0	.6			30.0	.3			14.0	.1	20.0	.2	73.0	1.3
8 Mele									20.0	.2					53.0	.8

[1] Percent presence

[2] Mean cover estimate

The proposed character species of the alliance, Acacia vernicosa, Larrea tridentata, and Flourensia cernua have high presence and cover which illustrates that these species are good identifiers for that phytosociological taxon. The proposed alliance has two associations:

Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri)

This phytosociological taxon has been named after its proposed character species, even though these species are annuals. However, the results of the analysis indicate that such species are as effective as any perennials in the identification of this phytosociological taxon.

Three subassociations and their respective differential species are shown in Table 6. Euphorbia micromera, Euphorbia setiloba, Prosopis juliflora, Scleropogon brevifolious and Euphorbia serpyllifolia are the differential species for Subassociations 1A, 1B, and 1C, respectively.

Association B (Rhus microphylla-Dalea formosa)

This unit has other important species in addition to the ones already described for the alliance that help to describe the association. The most important are Yucca baccata, Nolina microcarpa (in some instances occurring in dense, pure stands), Chamaesaracha coniodes and Verbesina rothrockii. This association is named for its character species. Rhus microphylla and Dalea formosa also occur in Association M (Mortonia scabrella) and in other vegetation units, but on the basis of their cover and vitality they fit the requirements for preferential character species in the association that bears their name (Becking, 1957). Five Sub-associations 2D, 2E, 2F, 2G, and 2H are distinguished in this phyto-sociological category. Subassociation 2D is a typical subassociation since it lacks differential species (Moore, 1962; Moore et al., 1970). The differential species of Subassociation 2E are Aristida divaricata and A. purpurea; of 2F Abutilon incanum; of 2G Euphorbia serpyllifolia, and of 2H Dasylirium wheeleri, Thamnosma texana, and Melampodium leucanthum.

The stands included in Alliance I (Acacia vernicosa-Larrea tridentata-Flourensia cernua) could be readily identified on the ground or by aerial and high altitude photography provided the ground checking and the photography is done during August, the peak of the growth season. After this date, the plant species drop their foliage and become difficult to identify on the ground (especially to a person unfamiliar with the vegetation); consequently, on the photographs the imaged features would be mostly soil surface characteristics.

Before leaving this alliance, an important point should be made with regard to the identification of this alliance and its subordinates. Notice in Table 6 that the number of character species for the associations is rather limited and more importantly, these species are annuals for Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri). A solution to this problem would be to call the association a typical one (Moore, 1962; Moore et al., 1970). This same problem is also faced at the subassociation level where Subassociations 1A, 1B, and 2G are identified by the use of just one annual species. This in turn may make it difficult to identify or differentiate some of these units in the field.

The Variant 1a

A potential taxon composed of five stands resulted from the analysis of the Mule Mountains data set. The area where these stands were documented lies on the southwestern-most edge of the study area on sites showing some degree of erosion, as evidenced by the presence of gullies. The vegetation may be characterized by the following species: Prosopis juliflora, Flourensia cernua, and Parthenium incanum are prominent in the tree and shrub layer. The herbaceous layer is restricted to the surroundings of the shrubs and trees for better protection and growing conditions. It consists of a few grass species such as Muhlenbergia porteri, Setaria macrostachya, Digitaria californica, Panicum obtusum, Bouteloua aristidoides, and Erioneuron pulchellum. The herbs Zinnia pumila, Sanvitalia abertii, Tidestromia lanuginosa, Perezia nana, and Apodanthera undulata are also present.

The stands comprising Variant la are phytosociologically more closely related to the stands found on alluvial terraces (as inclusions) of Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri) than to the stands found on Association I (Ayenia pusilla/Eragrostis intermedia) as can be seen from their species composition (Table 8). They both lack some of the character species of Alliance I (Acacia vernicosa-Larrea tridentata-Flourensia cernua). However, there are some basic differences that may help to determine the proper place of Variant la along the hierarchy. One of these is a somewhat higher cover of Prosopis juliflora (mesquite) in the former than in the latter although not enough to make this species a preferential character species (Becking, 1957). This species is also present on the stands belonging to Association H (Haplopappus tenuisectus/Eragrostis lehmanniana) that will be discussed soon. Consequently, P. juliflora is ruled out as a possible identifier.

Haplopappus tenuisectus is present along the alluvial terraces of Association A whereas it is absent from Variant la .

Following the concept of a variant (Braun-Blanquet, 1964) and attempting to maintain the initial hierarchy, I decided to group this taxon as a variant of Association A of Alliance I. This is the most logical and consistent alternative on the basis of presently available information.

Alliance II (Yucca elata/Bouteloua eriopoda)

The stands included in this alliance occupy the second most important portion of the study area. They extend eastward toward the Dragoon Mountains and Hay Mountain on areas highly dissected by a youthful drainage (Agricultural Research Service, 1967). The continuity of this unit is interrupted by a series of hills (Stockton and surrounding hills) causing a change in relief as one moves from north to south on the study area from the highly dissected to the gently rolling and undulating topography. This results in a slight change of vegetation from place to place as will be described later. The herb layer dominates the landscape; grass species such as Bouteloua eriopoda, B. curtipendula, B. hirsuta, B. chondrosioides, B. gracilis, Aristida barbata, A. divaricata, A. longiseta, A. wrightii, and Hilaria belangeri are the most prominent species. The most prominent species in the lower shrub layer are Calliandra eriophylla and Haplopappus tenuisectus. Ephedra trifurca is the most common species in the tall shrub layer, while Yucca elata is found scattered throughout the entire area where stands were observed. Prosopis juliflora, Quercus emoryi, Q. arizonica, Chilopsis linearis are restricted to areas of suspected heavier use, along the slopes and draws as one approaches the Dragoon Mountains and along the washes, respectively. As in the stands included in Alliance I, the most prominent species are the proposed character species for this alliance. However, while species that identify Alliance I are almost restricted to it, in Alliance II the character species are also found in other associations. On the basis of cover and vitality, however, these latter character species are preferents of Alliance II.

Most of the character species of this alliance have presence values higher than 50 percent in the different subassociations except Muhlenbergia arenicola, Aristida longiseta, Panicum hallii, and Croton corymbulosus which have 25 and 33 percent presence on Subassociations 1B and 3F; 38 and 33 percent presence in Subassociations 4G and 4H; 25, 38, and 33 percent presence in Subassociations 1A, 1B, and 3F; and 38 percent presence in Subassociation 1B, respectively (Table 7). Variation in the species distribution on higher rank units such as alliances is expected but it would not affect the validity of such species as identifiers of the alliances. It is strong representation of the group that identifies the alliance.

Four associations with their respective subassociations, character, and differential species are recognized in this unit. As in the previous alliance (Acacia vernicosa-Larrea tridentata-Flourensia cernua), the number of such species for the subordinant units is limited. However, each subordinant taxon is a reality and easily recognized in the field.

Table 7. Alliance II (Yucca elata/Bouteloua eriopoda).

	Association C (Gutierrezia sarothrae/ Eriogonum abertianum)				Association D (Menodora scabra/Tridens grandiflorus)				Association E (Hilaria belangeri)				Association F (Gila rigidula-Rhynchosia texana)			
Group	1A		1B		2C		2D		3E		3F		4G		4H	
No. stands/group	8		3		22		16		24		32		7		9	
Mean no. species/group	28.6		40.3		36.9		33.9		38.2		34.3		41.4		43.2	
	% P[1]	MCE[2]	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed character species of the alliance																
4 Yuel	88.0	1.1	100.0	1.7	77.0	1.0	63.0	.6	88.0	1.6	53.0	1.1	100.0	2.4	89.0	4.1
5 Boer	75.0	10.8	100.0	13.3	100.0	19.0	100.0	22.7	92.0	24.2	72.0	6.4	100.0	19.4	100.0	17.6
5 Muar 1	75.0	1.0	33.0	.3	77.0	2.1	44.0	.4	83.0	3.8	25.0	.4	100.0	7.4	89.0	2.9
5 Arlo	38.0	.4	33.0	.3	82.0	1.4	100.0	2.4	71.0	1.1	72.0	1.9	71.0	2.3	78.0	2.8
5 Paha	38.0	.4	33.0	.3	86.0	1.6	88.0	.9	63.0	.8	25.0	.3	71.0	.7	89.0	1.1
8 Crco	38.0	4.0	67.0	13.0	100.0	4.3	94.0	2.3	100.0	4.2	75.0	1.8	100.0	6.3	100.0	5.1
Proposed character species of Association C																
2 Gusa	75.0	1.0	100.0	4.0			31.0	.3	38.0	.4	31.0	.5			33.0	.6
9 Erab	75.0	.8	100.0	1.0	37.0	.4	13.0	.1	50.0	.8	31.0	.3				
Proposed character species of Association D																
2 Mesc					68.0	1.8	38.0	.4								
5 Trgr	13.0	.1			50.0	.6	50.0	1.0	25.0	.3						
Proposed character species of Association E																
5 Hibe					23.0	1.2	13.0	1.0	83.0	7.2	88.0	25.9	57.0	1.1	78.0	1.2
Proposed character species of Association F																
8 Hodr													100.0	1.4	44.0	.7
8 Giri													86.0	1.1	22.0	.2
8 Rhte													100.0	1.3	67.0	.7

(Continued on next page)

Table 7. (Continued).

	Association C (Gutierrezia sarothrae/Eriogonum abertianum)				Association D (Menodora scabra/Tridens grandiflorus				Association E (Hilaria belangeri)				Association F (Gilia rigidula-Rhynchosia texana)			
	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed differential species of Subassociation 1B																
9 Hagr			100.0	1.0												
9 Boco 1			100.0	1.0												
Proposed differential species of Subassociation 2D																
5 Arwr							94.0	4.6								
5 ARIST							75.0	1.4								
8 Peda							50.0	.5								
8 Pora							56.0	.7								
Proposed differential species of Subassociation 2E																
8 Oxla					9.0	.1			50.0	.5	3.0	.1	71.0	1.0	56.0	.6
Proposed differential species of Subassociation 3F																
7 Cyru							6.0	1			58.0	.6				
2 Erwr							6.0	.1	17.0	.2	75.0	.8				
8 Goca											56.0	.6				
8 Coin											50.0	.5				
Proposed differential species of Subassociation 4H																
8 Hode	22.0	.4													71.0	1.0

[1] Percent presence

[2] Mean cover estimate

Association C (*Gutierrezia sarothrae*/ *Eriogonum abertianum*)

Stands composing this association were recorded on the margins of the geographic area encompassed by Alliance II as witnessed by the presence of shrubs and other plant species characteristic of Association B of Alliance I. However, Association C has the Alliance II character species as well as its own set of character and differential species (Table 7). For these last two reasons and with the amount of information on hand, I would be inclined to place this unit at association level.

Two Subassociations, 1A and 1B, are found in this unit; the former lacks differential species so is "typical" (Moore, 1962; Moore *et al.*, 1970); *Haplopappus gracilis* and *Boerhaavia coulteri* are the differential species of Subassociation 1B.

Association D (*Menodora scabra*/ *Tridens grandiflorus*)

The stands included in Association D are found along the northeast fringe of the area encompassed by Alliance II. They appear to flourish on the more xeric slopes facing south and southwest. Some stands of this unit appear to overlap geographically with other stands which represent Association B of Alliance I since small outlying inclusions of B are found in D. Furthermore, both Associations B and D share several species in common such as Yucca baccata, Aristida pansa, and Chamaesaracha coniodes. Since this overlapping occurs among associations within different alliances, I have been unable at this time to pinpoint the environmental relationships or the autecological characteristics of the overlapping species that may account for their interrelationship. Poore (1955a) has suggested the term "transgressive faithful species" for those species which are faithful to one association of one alliance but which also occur in other associations within the same alliance. This definition agrees with Becking (1957) and gives us a conceptual basis for differentiating these kinds of character species from those that are more exclusive in their occurrence. One is able to show relationships among associations that do have significant ecological similarity but nevertheless can validly be differentiated on a species-group or multifactor basis into more than one phytosociological taxon. Association D has two well defined Subassociations, 2C and 2D; the former lacks differential species, that is, it is a "typical" subtaxon within the association (Moore, 1962; Moore et al., 1970). Aristida wrightii, Aristida sp., Penstemon dasyphyllus, and Polygala racemosa are the differential species for Subassociation 2D.

Association E (Hilaria belangeri)

The stands belonging to Association E occupy more restricted areas within Alliance II. They appear to be related to more mesic sites on the north and northwest facing slopes. The area where stands of this unit are found is almost entirely covered by Hilaria belangeri. The growth habit of this species (stoloniferous) make it rather difficult for other species to compete with it once it becomes established. However, other grass species such as Aristida barbata, A. divaricata, Bouteloua hirsuta and some shrubby species such as Haplopappus tenuisectus and Eriogonum wrightii are also present. Note in Table 7 that Hilaria belangeri is a preferential character species (Becking, 1957) since it occurs in other associations but its cover value is less. The Hilaria belangeri association has two Subassociations, 3E and 3F. The differential species of the former is Oxytropis lambertii (which is also present in Association F (Gilia rigidula-Rhynchosia texana) but not having differential value between the subassociations of Association F since it has higher presence in both subassociations; Eriogonum wrightii, Gomphrena caespitosa, Convolvulus incanum, and Cyperus rusbyi are the differential species of the latter.

Association F (Gilia rigidula-Rhynchosia texana)

The stands included in Association F are found on the east and southeast portions of the study area. The valley in which it occurs is surrounded by hills, on the north by the Stockton Hill, on the south by the Mule Mountains, on the east by Hay Mountain, and on the west by the Limestone Hills.

They occupy the gently rolling and undulating relief already described. The rest of the area is occupied by stands of other associations which interfinger with it somewhat; it has small patches of Acacia vernicosa. This situation has been documented before by Hastings and Turner (1966) and Wilcox, Little, and Schmutz (1965) in the sense that species characterizing the Chihuahuan Desert in southeastern Arizona such as Acacia vernicosa, Larrea tridentata, and Flourensia cernua are invading the desert grasslands as evidenced by the occurrence of small islands within it. Along the depressions and runnels, Prosopis juliflora, Haplopappus tenuisectus, and Bouteloua gracilis are present. Table 7 shows that only two Sub-associations, 4G and 4H, are distinguished. No differential species were identified for the former. Hoffmanseggia densiflora is the differential species for the latter.

Interrelationships Among Phytosociological Categories

At the beginning of the discussion of Alliance II, mention was made about some possible relationships among Associations B, C, and D belonging to different alliances as evidenced by the sharing of several species. It is quite possible that at one time Association B

(Rhus microphylla-Dalea formosa) and Association D (Menodora scabra/Tridens grandiflorus) were members of the same unit, the former being a more deteriorated stage of the latter as seen by the greater amount of shrubby species. This interpretation coincides with the general belief that local people have about the deterioration of the ranges since the time of the gold rush in the early 1880's in the Tombstone area. The only piece of evidence found in the literature which partially substantiates this belief is presented by Hastings and Turner (1966). Unfortunately, their photographic illustrations do not go further east than the Walnut Gulch.

The same reasoning can be applied to Associations C (Gutierrezia sarothrae/Eriogonum abertianum) and D (Menodora scabra/Tridens grandiflorus) of Alliance II when compared with a more typical member of the alliance such as Association F (Gilia rigidula-Rhynchosia texana). One could say that Associations C and D appear to be tending toward a "retrogressive" stage as seen by the "encroachment" of shrubs and the presence of less desirable species from the livestock grazing point of view. From the management point of view, Associations C and D would be difficult to treat separately since the combinations of stands which give rise to each association are phytosociologically similar and geographically intermingled.

Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii

This alliance is characterized by the presence of a mixed shrub grass vegetation. Fouquieria splendens-Acacia constricta-Aloysia wrightii are the most prominent species on the tall shrub layer. Parthenium incanum and Calliandra eriophylla are often present in the low shrub layer; Bouteloua eriopoda (black grama), B. curtipendula (sideoats grama) and B. chondrosioides (sprucetop grama) are most commonly found in the herb layer.

Due to the existing differences in elevation, relief, exposure, soil, amount of stones and bedrock in the soil surface, variations in the cover, prominence and distribution of species are expected to occur. A common feature of this alliance, as with others characterized by microphyllous species, is the phenology of Fouquieria splendens and Acacia constricta. Both species are leafless for most of the year, with foliage present only where moisture is available. This feature may make it difficult to identify this unit at the time when these species are leafless.

This alliance includes Association I (Ayenia pusilla/Eragrostis intermedia[12]), Association J (Cnidoscolus angustidens), and Association

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[12] Preferential character species.

K (typical[13] association). The data are presented in Table 8. After careful examination of each of the species occurring in the associations, it became apparent that there may be some relationship among them at a higher rank in the hierarchy. This fact was substantiated in a general way by the results of the analysis from the proportionate random sample (PRS). It appeared to indicate that species mentioned as character species of the alliance tie together each of its associations; the case is also true for other species on different areas. As can be observed in Table 8 the character species of Alliance III have 50 percent presence or over in all groups except Fouquieria splendens and Aloysia wrightii which have 11.0, 17.0, and 17.0 percent presence on groups 3E, 3F, and 3G, respectively. All the groups belong to Association K (typical association). Both species were included among the character species of the alliance since variations such as this are expected in units of this rank.

Some generalizations can be made about each of the associations composing this alliance in regard to their character species, the number of subassociations, and their differential species. I will discuss each association separately.

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[13] The concept applies to those associations or subassociations which lack character or differential species capable of separating them from the other associations or subassociations. Therefore, a typical association or subassociation has the same distinguishing features as the corresponding higher rank units. The context of the term appears to be related to the "typic" concept used for profile description in soil classification (Moore, 1962; Moore et al., 1970).

Table 8. Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii).

	Association I (Ayenia pusilla/Eragrostis intermedia)				Association J (Cnidoscolus angustidens)				Association K (Typical Association)					
Group	1A		1B		2C		2D		3E		3F		3G	
No. stands/group	13		13		6		20.		18		6.		6.	
Mean no. species/group	29.5		26.6		26.2		35.2		25.6		23.7		29.3	
	% P[1]	MCE[2]	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed character species of the alliance														
2 Fosp	85.0	23.7	54.0	2.0	100.0	4.7	90.0	9.6	11.0	.1	17.0	.2	50.0	.5
2 Acco	85.0	3.6	62.0	1.3	100.0	7.7	95.0	9.9	67.0	6.7	50.0	4.5	67.0	1.8
2 Alwr	62.0	1.6	69.0	2.5	100.0	4.5	95.0	19.6	72.0	8.3	83.0	6.3	17.0	3.0
Proposed character species of Association I														
9 Aypu	69.0	2.4	62.0	1.7										
5 Erin	62.0	4.2	100.0	10.4	40.0	1.5			28.0	.5	67.0	1.0		
Proposed character species of Association J														
8 Cnan					67.0	.7	65.0	1.7						
Proposed differential species of Subassociation 1A														
5 Boel	40.0	.8												
Proposed differential species of Subassociation 1B														
8 Sili			62.0	.6										
2 Sapa			54.0	.7										
8 Frar	38.0	.4	69.0	.7	17.0	.2	35.0	.5						
8 Vero	23.0	.2	85.0	1.3	17.0	.2	45.0	.6						
2 Eypo	46.0	.6	100.0	4.0	83.0	.8	25.0	.6	11.0	.2	83.0	2.3		
2 Acan	15.0	.2	85.0	1.9					22.0	.2	17.0	.2	17.0	.2

(Continued on next page)

Table 8. (Continued).

	Association I (*Ayenia pusilla*/*Eragrostis intermedia*)				Association J (*Cnidoscolus angustidens*)				Association K (Typical Association)					
	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE	% P	MCE
Proposed differential species of Subassociation 2C														
9 Scin					67.0	.7	5.0	.1						
5 Trgr					83.0	.8	25.0	.3						
2 Aymi					67.0	.7	10.0	.1						
8 Hacr					100.0	1.0								
2 BRICK					100.0	1.0								
5 Mupa					100.0	1.0								
5 Stem					100.0	1.0								
2 Testa					50.0	.5								
2 Hico	38.0	.4	38.0	.4	67.7	.7	5.0	.1						
Proposed differential species of Subassociation 2D														
2 Caer	100.0	7.5	77.0	5.4			65.0	1.5						
8 Jama	46.0	.5	54.0	.5			50.0	.6	38.0	.4	83.0	.8	67.0	.7
Proposed differential species of Subassociation 3F														
5 Muem	69.0	1.5					25.0	.3	17.0	.3	83.0	.8		
5 Bora	62.0	2.0							17.0	1.3	50.0	4.0		
Proposed differential species of Subassociation 3G														
4 Yuel									3.0	.1			83.0	.8

[1] Percent presence

[2] Mean cover estimate

Association I (Ayenia pusilla/ Eragrostis intermedia)

The stands of this association are found on the south and southeastern portion of the study area. Their distribution includes the northeast end of the Mule Mountains. It is identified by the presence of two character species Ayenia pusilla and Eragrostis intermedia (this last species is considered the preferential character species by Becking, 1957) from which it derives its name. There are also two subassociations each with their own differential species (Table 8).

The stands of Subassociation lA occupy portions of the alluvial fans and xeric slopes of the Mule Mountains. Bouteloua eludens is the differential species of this subassociation. As will be discussed later, , this subassociation is related to Subassociation 2D of Association J (Cnidoscolus angustidens).

The stands in Subassociation lB are located on the more mesic slopes at higher elevations. Acacia angustissima, Ehysenhardtia polystachya, Sisymbrium linearifolium are the differential species; Salvia parryi is an exclusive species of this association.

Evidences of past and recent fires appear in portions of the area occupied by this subassociation. Burned stocks of Agave palmeri, A. parryi and Dasylirium wheeleri disclose recent burns. The evidences of past fires are more difficult to prove--pure casual observations are not enough; however, one may be able to infer about their occurrence by the presence of isolated Quercus oblongifolia and Q. emoryi (oak trees) on isolated sites where there is a break of exposure and one might assume fires did not reach. Fire appears to have had a great influence in the increase of grass cover on burned areas, the most important species being Eragrostis intermedia, Bouteloua curtipendula, and B. radicosa. On the burned areas, Eysenhardtia polystachya is the only shrub present.

Association J (Cnidoscolus angustidens)

The stands included in Association J (Cnidoscolus angustidens) are found on the hills northwest of Tombstone as well as on the south and southwest facing escarpments of the Limestone Hills. Cnidoscolus angustidens is the character species of this association. It has two well defined Subassociations, 2C and 2D (Table 8). Standardized cover value estimates were used to classify this unit. The stands of Subassociation 2C are found in the south and southwest facing escarpments which show a well defined layering of the rock substratum. It has several differential species, the most important being Brickellia sp., Stipa eminens, and Muhlenbergia pauciflora. Tecoma stans var. angustata is an exclusive species of this subassociation.

Subassociation 2D has two species as differentials, Calliandra eriophylla and Jathropha macrorhiza (Table 8). They do not have differential value between the Subassociations 1A and 1B of Association I (Ayenia pusilla/Eragrostis intermedia) because they are equally present in both units. Likewise, Jathropha macrorhiza has no differential value in the case of Subassociations 3E, 3F, and 3G of Association K (typical association). Calliandra eriophylla and Jathropha macrorhiza, however, do differentiate between Subassociations 2C and 2D.

The stands included in Subassociation 2D have been described in the Walnut Gulch Experimental Watershed vegetation map (Agricultural Research Service, 1967) and named as the black grama-blue grama unit. With the information available, it is very difficult to accept the validity of such designators for the unit since Bouteloua gracilis (blue grama) was recorded in only three locations out of 26, that is, 11.5 percent presence; whereas Bouteloua eriopoda (black grama) had a 69.2 percent presence. This gives an indication that the unit was described by the ARS on the basis of what the vegetation would have been had no disturbance taken place. Poore (1956, p. 38) points out, "It would appear more reasonable to describe and characterize a plant community according to what it actually is than according to what it has been, or what it is thought to be about to become." From the floristic, vegetation, and geologic point of view (Gilluly, 1956; Arizona Bureau of Mines, 1959), there are evidences that indicate Subassociations 2D of this unit and 1A of Association I (Ayenia pusilla/

Eragrostis intermedia), already described, are somewhat related. These evidences are confirmed in part by the analysis of the data.

The validity of Association J (Cnidoscolus angustidens) may be questioned on the basis that it is defined on only one character species, but it also has a supporting unique set of differential species: Scin, Mupa, and Testa (Table 8). An alternative to this approach would be to describe it on the basis of its physiognomy. Using this feature, one may attempt to describe it as Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii) which are the proposed descriptors of the alliance.

Association K
(Typical Association)

This association lacks character species of its own as the name implies (Moore, 1962; Moore et al., 1970). It is recognized, therefore, by the species which identify the alliance and by the complete absence of character species which identify the other associations. The stands belonging to it are found on the isolated hills of basalt and andesitic bedrock (Gelderman, 1970) running from southeast to northwest and east to west of the study area. The vegetation is composed of a series of mosaics having different species depending upon soil characteristics, physical features (slope, exposure, elevation); thus in the swales between hills on the lower one-third of the slopes, Hilaria mutica (tobosa) is found along with grama grasses. In some instances on these slopes, tobosa is almost absent or appears as scattered bunches and a related species, Hilaria belangeri (curly mesquite) takes over on the middle, one-third of the slope. In some cases Acacia constricta takes over on the center one-third slope position and carries on through to the top of the hills where it becomes codominant with Aloysia wrightii which is also more common on the upper one-third of the slopes. Both species appear to be closely related to an increase in rocks and boulders on the soil surface. Aloysia wrightii, however, appears to be restricted to rims and mesas on these hills. Three subassociations are important in this association: 3E, 3F, and 3G. Since 3E lacks differential species, it is a typical subassociation (Moore, 1962; Moore et al., 1970). Muhlenbergia emersleyi, Bouteloua radicosa are the differential species of Subassociation 3F. Subassociation 3G has only Yucca elata as a differential species.

The complexity of the vegetation of this area is amazing in spite of the fact that other features such as geology are uniform (Gilluly, 1956; Arizona Bureau of Mines, 1959), this latter being wholly andesitic. In at least some of the areas included in the range of this association, there appears to be just one soil series, Graham, and several phases (Gelderman, 1970). The only way this complexity can be further unraveled or explained will be through more intensive sampling and studies of association environmental conditions.

Problems in Blocking Differential Species

Before leaving this alliance, some comments would be appropriate about a group of taxa that I consider valid and which are identifiable in the field but which do not show good blocking of character and differential species as a result of the classification analysis. These are: Association D (Menodora scabra/Tridens grandiflorus) and Association E (Hilaria belangeri) belonging to Alliance II (Yucca elata/Bouteloua eriopoda); Association A (Panicum hirticaule/ Tidestromia lanuginosa-Boerhaavia coulteri) and Association B (Rhus microphylla-Dalea formosa) of Alliance I (Acacia vernicosa-Larrea tridentata-Flourensia cernua); and Association K (typical association) of Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii).

1. All of these phytosociological taxa are defined by data sets having 69, 66, 60, and 58 stands, respectively.
2. The only pattern shown by these units comes from those species generally having the highest presence and cover, that is, high prominence.
3. The blocking found upon classification of these associations is limited to a few species. This lack of differentiating species introduces some doubt to the casual reader about the validity of such units even though they can be identified in the field. The fact that the small differences were

consistent for such large numbers of stands plus Becking's (1957) statement that "only character species of vegetation units of highest classificatory rank (order, class) are the more common and often locally dominant species" led me to separate the above taxa into three alliances and to set each taxon at association level.

The operational limitations of the "package of programs" used in the present study have been pointed out (Table 3) with regard to the number of stands and species that can be used to effectively classify a data set. It is expected that one can classify any data set with the program within the specifications mentioned before, from 3 to 70 stands and 3 to 90 species if the information contained therein is uniform, that is, the number of species do not increase considerably with the number of stands included in each set.

At the moment, it is difficult to ascertain whether the lack of blocking which occurred in the four data sets (CD, DR, BR and AH) was caused by the inclusion of too many stands per set or rather by the inclusion of stands somewhat unrelated to the set under investigation.

This same sort of problem was identified by Ceska and Roemer (1971) when they also were working with large numbers of stands per group. Although these workers were using different criteria from those which I used, their study had the same objective, i.e., to obtain groups or block formation. The possible reasons for the lack of blocking in data sets CD, BR, DR, and AH are as follows:

1. Too many stands were included in each operational data set from which the associations and subassociations were developed by the classification procedure. The best groupings for my data occurred when stand members ranged from 24 to 43 which agrees with Ceska and Roemer's findings in regard to their suggested optimum group size--30 stands per group.

2. A lack of discontinuity may exist within the data sets under consideration.

3. Too many species per data set may have been included in the classification. For data sets CD, DR, BR, and AH, the number of species was 86, 38, 65, and 43, respectively. This could have been reduced by:

   a. Adhering to the phytosociological rule of only working with species below 66 percent presence (constancy in case of plot data) on the assumption that species with higher presence (constancy) do not contribute to the differentiation among taxa except in the case of the preferential species. The same is true for those species having a low presence percent. In this work the latter species were deleted from the file after the program SORT was used to comply with the limitations of the programs. Ceska and Roemer (1971) have suggested several combinations of the relative lower presence limits within a group versus upper relative presence limit in any other group or unit at the same hierarchical level. Their suggested values in the former range from 10 to 33 percent and in the latter their values range from 50 to 66 percent. In my analysis the lower presence for inclusion ranged from 8.7 to 20.8 percent (Table 3). No upper limit for inclusion was specified, thus, in some cases species having up to 100 percent presence were included.

b. Using more stringent cluster techniques (decreasing the Euclidean distances among species and/or stands under consideration).

c. Increasing the number of stands and species required to form a cluster as an operational constraint in the program (two of both were used in all of the cases studied). This gave the classification program optimum opportunity to find differential groups.

d. Increasing the lower presence limit required for species to enter into the classification.

4. Potential differentiating species for groups may have been lost through retrogression.

Association G (*Hilaria mutica/Eriochloa gracilis/Crotalaria pumila*

Stands of this unit are found primarily on five sites: 1) valley bottoms, 2) alluvial terraces, 3) runnels, 4) swales, and 5) lower slopes of the Andesite Hills. Examples of the first four sites are found along Government Draw and as inclusions on Association A where they form stripes or patches conforming very much with the increase in soil moisture and soil depth on those sites. In both cases *Hilaria mutica* (tobosa) can occur either as pure stands or associated with other grass species such as *Boutloua curipendula* (side-oats grama), *B. gracilis* (blue grama), and *Sporobolus wrightii* (sacaton). *Prosopis juliflora* (mesquite) and *Rhus microphylla* (sumac) are found scattered on this vegetation unit. On site number five, *Hilaria mutica* is found in pure stands or as scattered bunches mixed with *H. belangeri* (curly mesquite). It appears that under the "fidelity concept" *H. mutica* cannot then have a fidelity class of V (exclusive). Instead, I would be inclined to call it a "preferential" character species because it is not limited to one area alone. Without having environmental data to confirm my observations, its distribution within this

Table 9. Association G (Hilaria mutica/Eriochloa gracilis/ Crotalaria pumila).

Group	1A		1B	
No. of stands/group	7		5	
Mean no. of species/group	33.3		32.2	
	Percent presence	MCE[1]	Percent presence	MCE
Proposed character species of Association G				
5 Himu	100.0	44.6	100.0	39.4
6 Ergr	86.0	4.9	80.0	9.0
9 Crpu	57.0	.9	80.0	2.6
Proposed differential species of Subassociation 1B				
8 Taau	14.0	.4	100.0	1.4
6 Arad	14.0	.4	100.0	3.8
5 Erpu	14.0	.1	60.0	.6
2 Acve	29.0	.3	100.0	1.0
8 Alin			60.0	2.0
5 Arlo			60.0	.6
8 Baab			60.0	.6
2 Bapt			60.0	.6
5 Boer			80.0	2.6
8 Caba			60.0	.6
8 Crco			60.0	1.0
9 Dale			60.0	.6
9 Erab			60.0	.6
5 Ende			60.0	1.0
9 Euse 1			100.0	2.2
3 Opvim			60.0	.6
2 Pain			60.0	.6
9 Popa			60.0	.6
8 Sipr			80.0	1.2

[1]Mean cover estimate

community apparently is related to edaphic conditions. Herbel (1963) reports that tobosa "occurs primarily on heavier textured soils, but it is not limited to them." Two Subassociations, 1A and 1B, are recognized within this association. Subassociation 1A does not have any differential species, it is "typical" (Moore, 1962; Moore et al., 1970) and 1B has many (Table 9).

Association H (Haplopappus tenuisectus[14]-Eragrostis lehmanniana)

Stands of this association intergrade somewhat with stands of the Association F (Gilia rigidula-Rhynchosia texana). It occupies a flat relief interrupted by depressions and it appears to be uniquely associated with reddish and reddish-brown soils. Some important features of this taxon are: (1) The presence of Prosopis juliflora in some stands of this association as isolated trees or patches on soil mounds. As a result of this and due to the ability of this species to compete with others, the interspaces are bare or occupied by annuals or short-lived perennials. The most immediate result of the bare soil (plus the type of precipitation and possibly the land use pattern) is the acceleration of the erosion process which is already commonly evidenced by the presence of gullies. (2) Eragrostis lehmanniana, an introduced grass, sometimes occurs in small patches or occupying

[14] Preferential character species.

extensive areas. This species is one of three lovegrasses introduced into this country by the Soil Conservation Service in the early 1930's (Crider, 1945). Its main use has been in the revegetation of the drier portions of southwestern ranges and burned areas on national forests and other public lands. No record was found concerning how it became established in this area, although Cable (1971) pointed out that the species was used in some revegetation trials between 1945 and 1954 to determine its adaptability to various soil and rainfall conditions and various seeding methods. Its presence and aggressiveness certainly are evident even on areas where mesquite has taken over (Cable, 1971); therefore, it appears that its presence is an asset to these ranges. An analysis of the pros and cons of this species is given by Cable (1971). However, he fails to make appropriate statements about its possible values in the prevention of soil erosion.

Before ending the discussion of this association, the presence of two well defined Subassociations (1A and 1B) should be mentioned as evidenced by their differential species (Table 10), *Acacia greggii*, *Proboscidea arenaria* and *Mollugo verticillata* in the former; *Evolvulus sericeus*, *Zinnia grandiflora*, and *Bouteloua gracilis* in the latter.

The associations included in the *Yucca elata*/*Bouteloua eriopoda* Alliance II (Table 7), the *Hilaria mutica*/*Eriochloa gracilis*/*Crotalaria pumila* and the *Haplopappus tenuisectus*/*Eragrostis lehmanniana*

Table 10. Association H (Haplopappus tenuisectus/Eragrostis lehmanniana).

Group	1A		1B	
No. of stands/group	11		13	
Mean no. of species/group	33.4		39.0	
	Percent presence	MCE[1]	Percent presence	MCE
Proposed character species of Association H				
2 Hate	100.0	8.2	92.0	5.5
5 Erle	73.0	2.2	85.0	17.0
8 Evar	55.0	.9	69.0	1.7
6 Chvi	36.0	1.0	62.0	.6
6 Boar	82.0	5.5	38.0	1.1
Proposed differential species of Subassociation 1A				
2 Acgr	55.0	4.9		
9 Prar	55.0	2.8		
9 Move	55.0	.7		
Proposed differential species of Subassociation 1B				
8 Evse	19.0	.2	77.0	1.5
8 Zigr			92.0	1.2
5 Bogr			85.0	2.2
2 Deco			69.0	1.0
9 Ipco 1			54.0	.7

[1]Mean cover estimate

Associations correspond very closely to the four communities into which Shantz and Zon (1924), as cited by Humphrey (1953), divide the desert grassland on the basis of dominant species:

1. Bouteloua eriopoda (black grama) to Association F (Gilia rigidula-Rhynchosia texana)
2. Hilaria belangeri (curly mesquite) to Association E (Hilaria belangeri)
3. Hilaria mutica (tobosa grass) to Association G (Hilaria mutica/Eriochloa gracilis/Crotalaria pumila)
4. Bouteloua rothrockii (crowfoot or Rothrock grama) not correponding to any specific unit

However, Boutelous rothrockii is found only in patches along the alluvial terraces on the study area. Both classifications are based on two completely different concepts--dominance and faithfulness. Even though differently named, they lead to recognizably similar classes.

Association L (Agave palmeri-Agave parryi/ Haplopappus laricifolius)

The stands included in this unit are found on the eastern part of the study area occupying the hills south of the Dragoon Mountains. These hills are geologically uniform (Gilluly, 1956; Arizona Bureau of Mines, 1959). The vegetation of this association has two character species (Agave palmeri and A. parryi) with a fidelity class IV (selectives). However, since these species are also present in

Association I (Ayenia pusilla/Eragrostis intermedia) and others, both species are classified as preferents. Haplopappus laricifolius, however, appears to be a good character species for the association.

This association has two subassociations, 1A and 1B, each one having several differential species (Table 11). Sphaeralcea grossulariaefolia, Desmanthus cooleyi, and Hilaria belangeri; Brickellia venosa, Heteropogon contortus, and Elyonurus barbiculmis are the differential species of Subassociations 1A and 1B, respectively.

Subassociation 1A appears to be closely related to the Hilaria belangeri association of Alliance II as evidenced by the presence of this species and others. The difference between these associations is the presence of the Agave spp. and Haplopappus laricifolius in the former and their absence in the latter. Furthermore, the character species of the Alliance II have low presence and some of them are absent in Association L. An important feature of Subassociation 1B is the exclusive occurrence of Elyonurus barbiculmis which sets Subassociation 1B clearly aside from all other taxa.

Association M (Mortonia scabrella)

The most striking feature about the stands on this association is their physiognomy and distribution. The association has Mortonia scabrella as the outstanding prominent and as its character species. It has two well defined Subassociations, 1A and 1B, with their

Table 11. Association L (*Agave palmeri*-*Agave parryi*/*Haplopappus laricifolious*).

Group	1A		1B	
No. of stands/group	14		14	
Mean no. of species/group	28.6		29.7	
	Percent presence	MCE[1]	Percent presence	MCE
Proposed character species of Association L				
4 Agpa	64.0	1.4	79.0	1.6
4 Agpa 1	64.0	1.4	93.0	4.2
2 Hala	36.0	1.7	71.0	1.3
Proposed differential species of Subassociation 1A				
8 Spgr	64.0	.8		
2 Deco	64.0	1.1		
5 Hibe	86.0	16.0		
9 Dale	57.0	.9	7.0	.1
2 Hate	71.0	.9	14.0	.1
Proposed differential species of Subassociation 1B				
5 Anci	14.0	.1	64.0	4.1
5 Trmo	7.0	.1	50.0	1.0
9 Move	7.0	.1	57.0	1.0
2 Krpa	21.0	.2	86.0	1.6
5 Elba			79.0	3.0
8 Brve			57.0	.6
5 Heco			86.0	1.6

[1]Mean cover estimate

respective differential species (Table 12). These results came about using standardized cover value estimates. The stands of Subassociation 1A appear to be restricted to the north and northeast cuesta limestone formations. Leptochloa dubia, Cercocarpus breviflorus, and Muhlenbergia pauciflora are differential species. Rhus chloriophylla, Heterosperma pinnatum, and Thelesperma longipes are exclusive species of this subassociation.

Stands of Subassociation 1B are found in the alluvial fans adjacent to the Limestone Hills, and are closely related to Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri) and Association B (Rhus microphylla-Dalea formosa) of Alliance I (Table 6), previously discussed. Several species such as Koeberlinia spinosa, Opuntia leptocaulis, Coldenia canescens, and Setaria macrostachya are the differential species for this subassociation.

The vegetation of Association M (Mortonia scabrella) as a whole has been identified in previous work (Agricultural Research Service, 1967) as the mortonia-whitethorn-creosote bush vegetation unit. According to the ARS report this unit is restricted to three soils underlain by solidified caliche. It is my feeling, however, on the basis of my field observations, that this statement would be accurate only in the case of Subassociation 1B. In Subassociation 1A, this would not be accurate since most stands are restricted to the Limestone Hills where limestone underlying shallow soils is the most

Table 12. Association M (Mortonia scabrella).

Group	1A		1B	
No. of stands/group	12		12	
Mean no. species/group	46.58		38.10	
	Percent presence	MCE[1]	Percent presence	MCE
Proposed character species of the association				
5 Mosc	100.0	13.4	100.0	16.6
Proposed differential species of Subassociation 1A				
6 Arad	92.0	6.3	25.0	.3
2 Qupu	92.0	11.0	25.0	.6
5 Stem	92.0	2.2	25.0	.1
2 Acco	75.0	2.2	25.0	.6
2 Eypo	92.0	1.3	16.7	.2
5 Muem	83.0	1.2	8.0	.1
5 Erin	75.0	.8	8.0	.7
6 Mumi	67.0	.7	8.0	.1
5 Ledu	92.0	.9		
2 Cebr	75.0	.8		
2 Rhch	75.0	1.1		
5 Mupa	67.0	.8		
9 Hepi	50.0	.5		
8 Pesc	50.0	.5		
9 Potr	50.0	.5		
0 Nosic	50.0	1.3		
Proposed differential species of Subassociation 1B				
2 Cosp	16.7	.2	92.0	1.4
2 Acve	16.7	.3	75.0	7.3
2 Latr	16.7	.3	83.0	3.8
2 Kosp			58.0	.8
3 Ople			67.0	.7
5 Sema			67.0	1.0
2 Coca			50.0	1.0

[1]Mean cover estimate

common environmental feature, but as mentioned, Mortonia scabrella is also present. If all these statements about Subassociations 1A and 1B hold true, these units are in agreement with the concept described by Braun-Blanquet (1964)--namely, that such sub-units are determined by edaphic factors, local climate, or geographic relationships.

An attempt was made to consider the stands of this association as part of the Alliance I in lieu of its relationships with the components of that unit. Mortonia scabrella is present along with Acacia vernicosa, Larrea tridentata, Flourensia cernua, Nolina microcarpa, and Yucca baccata on the alluvial fans adjacent to the Limestone Hills. Quercus pungens (in patches) and Cercocarpus breviflorus occur on the higher elevation of the Limestone Hills. This is particularly true for the stands of Subassociation 1B and to some degree for those of Subassociation 1A. The former have many species in common with Alliance I (Table 6), except for Mortonia scabrella. Subassociation 1A, on the other hand, has some species found in the other associations of Alliance I and also some others unique to itself. With the information now on hand I am more inclined to let the Association M (Mortonia scabrella) stand alone than to combine it with others in an alliance.

The Proportionate Random Sample

Analysis of the tenth data set accomplished what was intended at the time the analytical plan was conceived. It yielded a repetition of the classification pattern from the original nine groups (CD, . . ., LH) from which the sample was drawn. The analysis did show three well defined groups having 14, 13, and 10 stands each. In addition, two non-conformist[15] groups of three stands each were identified from the analysis. These were not comparable to any classes developed from the initial analysis of the nine separate groupings.

Random drawing from the nine sets cannot necessarily be expected to adequately sample all taxa identified from the original data sets. It could be that these six stands were classified into two new sets because all of the original taxa were not represented in the random set. It would appear that comparable classes into which this new taxa could have been grouped were missing from the smaller random set, whereas a sufficiently close fit to a different group was achieved for each of them in the initial analyses of the larger sets of data.

In the first group, 12 out of 14 stands (85.7 percent) corresponded to Alliance I (<u>Acacia vernicosa</u>-<u>Larrea tridentata</u>-<u>Flourensia cernua</u>) and the other two corresponded to two different associations of other alliances. According to the classification output and the graphical representation of it (dendrogram) these 14 stands have two

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[15] Members of a group being rather unlike everything else including each other (Lance and Williams, 1967).

subgroups of seven stands each.

Of the first subgroup of seven stands, six (85.7 percent) belong to Association A (Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri) of Alliance I (if the subgroup is regarded as an association). The other stand belongs to Association B (Rhus microphylla-Dalea formosa); Boerhaavia coulteri is the character species of this set of seven stands. This illustrates the rather high percentage recovery of taxa from the original classification in this subgroup of seven randomly selected stands.

In the second subgroup of seven stands, three stands were recovered (42.8 percent) as members of the Association B of Alliance I, and the character species of this group also turned out to be Rhus microphylla and Dalea formosa. Even though recovery was only 42.8 percent, it was important that the character species be faithfully reproduced for this taxon by analysis of the smaller random sample. Two of the seven stands (28.6 percent) belong to Association A from the initial classification but they were separated as a unique subgroup in this analysis. The remaining two stands in this subgroup represent Association M (Mortonia scabrella), and Association K (typical association) of Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii).

In the second group, 12 out of the 13 stands (92.3 percent) corresponded to the Alliance II (Yucca elata/Bouteloua eriopoda), the other is included in Association L (Agave palmeri-Agave parryi/ Haplopappus laricifolius). Following the same reasoning as in group one, that is, to consider the subgroups as associations, three such units with 5, 4, and 4 stands each can be recognized. In the first association, three out of five stands (60.0 percent) belong to Association E (Hilaria belangeri), the other two (40.0 percent) correpond to Association F (Gilia rigidula-Rhynchosia texana). Enneapogon desvauxii is again identified as the character species for the set of five stands.

In the second association, three out of four stands correspond to Association D (Menodora scabra/Tridens grandiflorus) and the other belongs to Association E. Opuntia violacea var. macrocentra is again the character species for the set of four stands. The third association has four stands, three belong to Association E, the other to Association L. The inclusion of the latter is not surprising, since both units E and L are somewhat related (see p. 85). Desmanthus cooleyi and Dalea lemmonii are the character species for this four-stand set.

The third group contains ten stands, six of them (60.0 percent) correspond to Alliance III (Fouquieria splendens-Acacia constricta-Aloysia wrightii), two correspond to Association L, and the other two correspond to Associations B and M. In this analysis, however, two subgroups having five stands each are recognized. The first set contains five stands, two of which (40.0 percent) correspond to Association I (Ayenia pusilla/Eragrostis intermedia); two (40.0 percent) correspond to Association L, and the other (20.0 percent) to Association B. Evolvulus arizonicus is the character species of this latter set of five stands. The other set has five stands, three of them correspond to Association J (Cnidosculus angustidens) of Alliance III. The stands of this unit were reproduced faithfully. The other two stands correspond to Associations M and K, respectively. No character species for this set of five stands were identified.

Although highly subjective and based on a combination of geographic, physiognomic, physiographic, and phytosociological features, the criteria used to break the original data into nine subsets to meet the capacity limitations of the computer program appear valid. Had this not been true the acceptable levels of correspondence between results from treatment of the total data set versus analysis of a Proportionate Random Sample of 43 stands would not have been realized.

A summary statement about the Proportionate Random Sample (PRS) can be made as follows. The groups included in an alliance were reproduced on a percentage-wise basis from 60.0 to 92.3 percent. The agreement among stands classified at association level was not as good as at the alliance level. In some cases only 33.3 percent of the stands were classified in the same association (as in the LH and AH groups) but in one case 100 percent agreement was achieved (in the TH set). Table 13 compares the classification of the stands in each of the nine groups as determined by the PRS analysis. The PRS analysis did not effectively identify the subassociation level.

The refinement at which one may classify a vegetation with this method is strongly a function of sample size in relation to the minimum detectable subgroup. For any one hierarchical level of classification, there is apparently a minimum sample size for ideal results; and our collective work to date has not identified this limit.

While there is considerable subjectivity and judgment in the determination of group and subgroup level (alliance, association, or subassociation) from study of the dendrograms and analytical data output, these decisions can be made quite consistently. This exercise of judgment cannot be avoided and is an integral part of the human-computer interaction in the analytical process. The validity of this approach to classification, with the necessary human-machine interaction, is strongly supported by the following: (1) The analysis of both the full data set and the PRS set identified the same alliances and many of the same associations within each, (2) the same set of character species was identified by both approaches as well as the Stepwise Discriminant Analysis (see later), and (3) these sets of character species do correspond to natural phytosociological groups of plants that are found to occupy repeated landscapes.

Table 13. Comparison of classification, Proportionate Random Sample (PRS) with total data analysis.

Data set	Initial analysis total data (No. of stands)	Proportionate Random Sample Analysis		
		No. stands selected	No. stands classed same	% Classed same, "recovery"
CD	69	7	5	71.4
BR	60	6	3	50.0
DR	66	7	3	42.8
AH	58	6	2	33.3
MU	43	4	2	50.0
KR	40	4	3	75.0
GR	32	3	2	66.7
TH	26	3	3	100.0
LH	24	3	1	33.3

Stepwise Discriminant Analysis (SDA)

This analysis was accomplished on the vegetation groupings resulting from the classification process on each of the ten data sets (CD, . . ., PRS) once the process was completed. The rationale behind this step was to determine how well the proposed character and differential species identify the associations and subassociations. Two runs per data set were carried out. Most of the groups considered in the first run represent either associations or subassociations (except PRS). In addition, these groups were subdivided into subgroups according to the similarities or differences, or both, that were observed in the classification outputs and the dendrograms. They were analyzed on the second run and represented mostly subassociations and other lower rank units.

The results of the second run, however, indicate that these units provide information useful only for academic purposes. They may suggest, however, the presence of variations on the landscape due to microsite differences which are observed on the ground, and mappable on conventional aerial photography, but due to their size and importance there is no justification for considering them as separate units from the management point of view. Furthermore, the differentiating power of certain species was so overwhelming at the first hierarchical level that their effects were felt even at the second level to the point that, in some cases, they obliterated some potential differential species which could have identified some subgroups. The discussion of the SDA at the second hierarchical level on each of the data sets is included. A summary of the whole process on both levels is presented in Appendix Table 2.

The information extracted from the analysis that is relevant to the present study is:

1. Number of species required to achieve a perfect discrimination.
2. Number of species required to separate pairwise differences among group and subgroup means at a .01 probability.
3. Number of the canonical variables required to account for the total dispersion.
4. Plots of the first canonical variable against the second to observe the group separation.
5. Comparison of the best discriminating species from this analysis with the differential species resulting from the classification.

The Chihuahuan Desert (CD) Data Set

In the SDA of the CD set having two groups with 49 and 20 stands each, the former corresponds to Association A (Panicum hirticaule/ Tidestromia lanuginosa-Boerhaavia coulteri) and the latter corresponds to Subassociation 2D of Association B (Rhus microphylla-

Dalea formosa), respectively. Thirty-eight out of 40 species selected were required at the first hierarchical level to achieve perfect discrimination. Dalea formosa (Dafo) and Bouteloua curtipendula (Bocu) were the first and second best discriminants, respectively. However, the latter species and Sporobolus wrightii (Spwr) which entered at the second and eleventh steps were removed from the process at the twenty-first and thirty-ninth steps, respectively. The pairwise difference between the group means showed significance at the .01 probability level with the inclusion of Dalea formosa at the first step.

The results of plotting the first versus the second canonical variable is presented in Figure 3. The most important point that should be made from that figure is the within groups dispersion being more evident in group B. As in the other units tested which have two groups each, the second canonical mean coordinate value is 0 for both groups and the values of the first canonical means are different; the group having the larger number of stands being nearer to the origin. The first canonical variable accounts for the total dispersion.

At the second hierarchical level of this set, four subgroups having 33, 16, 15, and 5 stands were considered. The first two subgroups include Subassociations 1A, 1B, and 1C of Association A, and the other two subgroups correspond to Subassociation 2D (Table 14). Twenty species out of 24 used in the SDA were required to obtain

Table 14. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of Chihuahuan Desert (CD) data set.

Step	Species entered	Subgroup	1A	1B	2C	d. f.
1	Dafo	1B	3.97			1 65
		2C	31.92**	10.27**		
		2D	10.77**	3.56	.12	
2	Soel	1B	13.39**			2 64
		2C	19.44**	6.48**		
		2D	7.86**	2.01	.16	
3	Dapo	1B	10.19**			3 63
		2C	12.78**	5.01**		
		2D	10.92**	10.05**	5.51**	
⋮						
8	Zipu	1B	12.23**			8 58
		2C	10.53**	3.37**		
		2D	6.94**	6.06**	2.82*	
9	Popa	1B	12.48**			9 57
		2C	11.64**	2.99**		
		2D	7.21**	5.28**	2.47*	
10	Latr	1B	11.08**			10 56
		2C	10.62**	3.10**		
		2D	7.78**	6.20**	2.76**	
⋮						
20	Euse 2	1B	6.55**			20 46
		2C	8.10**	3.38**		
		2D	7.05**	5.98**	4.29**	

*, ** Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 3. Group separation obtained from plotting the first canonical variable (x), against the second canonical variable (y), at the first hierarchical level of the Chihuahuan Desert (CD) data set.

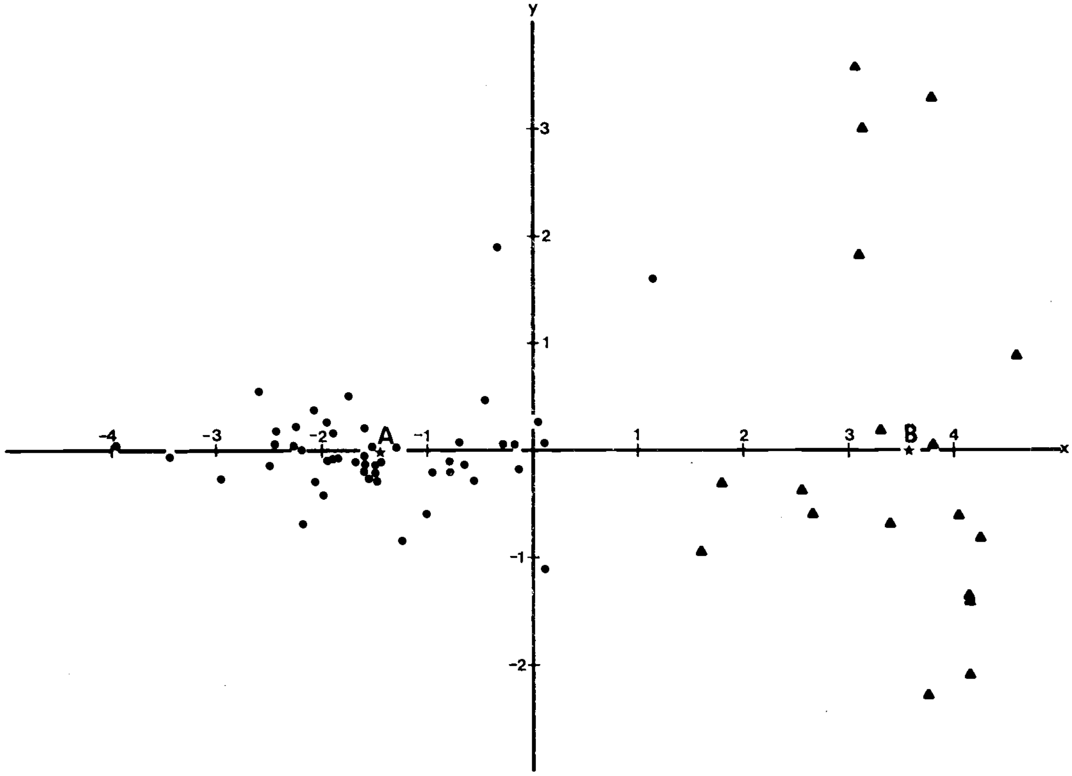
Group A represents Association A (Panicum hirticaule/ Tidestromia lanuginosa-Boerhaavia coulteri). Group B correspolds to Subassociation 2D of Association B (Rhus microphylla-Dalea formosa).

* Indicates group means.

Figure 4. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Chihuahuan Desert (CD) data set.

Subgroups 1A and 1B correspond to Subassociations 1A, 1B, and 1C of Association A (Panicum hirticaule/ Tidestromia lanuginosa-Boerhaavia coulteri). Subgroups 2C and 2D correspond to Subassociation 2D of Association B (Rhus microphylla-Dalea formosa), respectively.

*Indicates subgroup means.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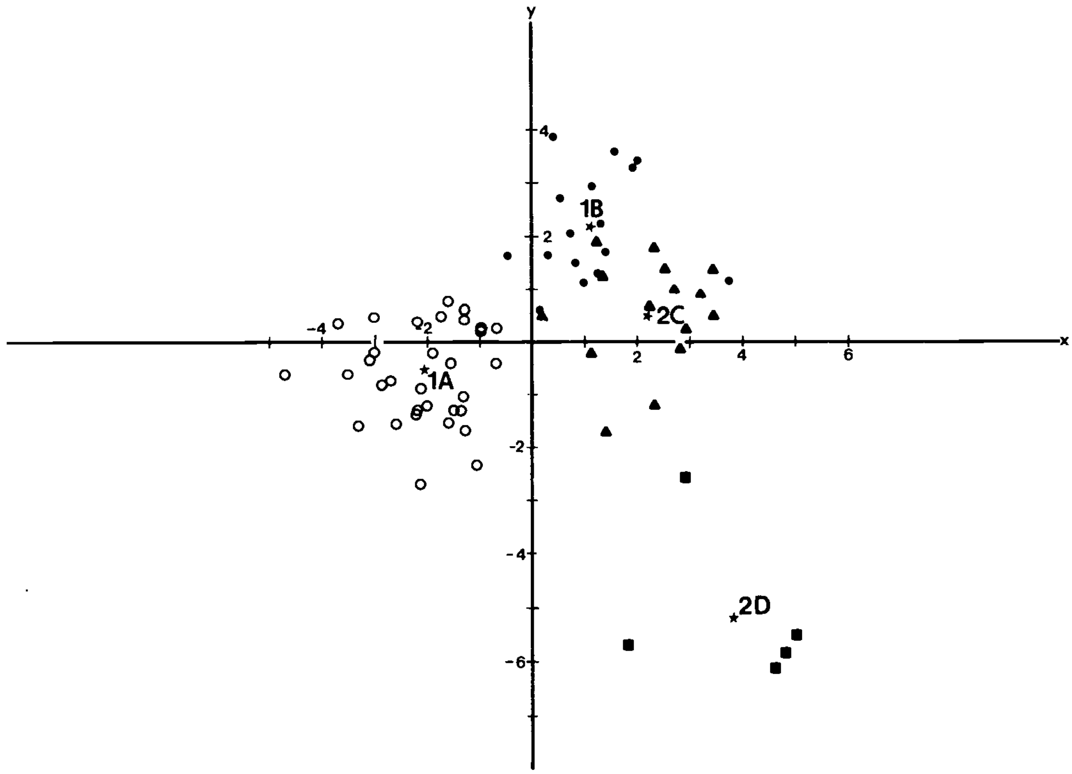
x
A
B
-4
-3
-2
-1
1
2
3
4
-1
-2


y
x
1A
1B
2C
2D
-4
-2
2
4
6
-2
-4
-6

a perfect discrimination. Dalea formosa (Dafo) was again the best discriminant and Solanum eleagnifolium (Soel) was the second best.

Significance at the .01 probability level among the subgroups was obtained by the entrance of Dalea pogonathera (Dapo) at the third step. This value remained unchanged until Zinnia pumila (Zipu) and Portulaca parvula (Popa) entered the process at steps eight and nine, lowering the probability level between groups 2C and 2D to .05. The entrance of Larrea tridentata (Latr) at the tenth step increased the F value between subgroups 2C and 2D back to significance at P = .01; this value remained unchanged among all the subgroups throughout the process (Table 14).

The results of plotting the first versus the second canonical variable (Figure 4) indicate subgroups 1B and 2C overlap somewhat (in a two dimensional plot), whereas subgroups 1A and 2D are well defined. The total amount of dispersion is accounted for by the first three canonical variables; the first and second accounting for 50 and 86 percent, respectively.

The Brushland (BR) Data Set

Five groups of 10, 14, 10, 15, and 11 stands were analyzed in this group. The first four groups represent Association B (Rhus microphylla-Dalea formosa). The last group (11 stands) represents Association C (Gutierrezia sarothrae/Eriogonum abertianum).

Thirty-two species out of a total of 36 were required to attain a perfect discrimination. Eriogonum abertianum (Erab) and Abutilon incanum (Abin) were the first and second best discriminants. Euphorbia revoluta (Eure) entered the process at the seventh step and provided separation of the pairwise differences among group means at a .01 probability: From this step to the eighteenth, the probability level between groups C and D dropped off to .05. The inclusion of Menodora scabra (Mesc) on the nineteenth step raised the probability up to .01 again and it remained at this level until the end of the process (Table 15).

The results of plotting the first versus the second canonical variable are presented in Figure 5. Observe that the only group well defined is E, Association C. The rest of the groups are so close to each other that it would be difficult to separate them. There is even some overlapping of cases among two different groups (C and D) which indicates that perhaps they should be consolidated as a group. Ninety-five percent of the dispersion is accounted for by the first two canonical variables, the rest belongs to the third and fourth.

At the second level on this set, ten subgroups were considered with 7, 3; 9, 5; 5, 5; 9, 6; 8 and 3 stands each corresponding to Subassociations 2E, 2F, 2G, 2H; 4G, 4H of Associations B (Rhus microphylla-Dalea formosa) and C (Gutierrezia sarothrae/Eriogonum abertianum), respecitvely. Thirty-three out of 36 species were required

Table 15. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of the Brushland (BR) data set.

Step	Species entered	Group	A	B	C	D	d. f.
1	Erab	B	0				1 55
		C	0	0			
		D	.57	.68	.57		
		E	75.05**	88.25**	75.05**	76.71**	
2	Abin	B	17.11**				2 54
		C	0	17.11**			
		D	.42	17.96**	.42		
		E	36.93**	58.76**	36.39**	37.66**	
3	Ardi	B	22.58**				3 53
		C	11.53**	11.28**			
		D	10.66**	11.80**	.52		
		E	27.37**	40.77**	26.99**	26.44**	
4	Boch	B	16.75**				4 52
		C	8.74**	8.34**			
		D	7.89**	8.71**	.50		
		E	36.05**	52.06**	40.24**	40.76**	
5	Arad	B	13.14**				5 51
		C	6.87**	6.56**			
		D	6.23**	6.89**	.39		
		E	64.62**	83.75**	66.33**	73.28**	

(Continued on next page)

Table 15. (Continued)

Step	Species entered	Group	A	B	C	D	d. f.
6	Mele	B	10.89**				6 50
		C	5.78**	5.36**			
		D	5.93**	7.72**	2.18*		
		E	67.16**	82.16**	65.58**	86.05**	
7	Eure	B	9.15**				7 49
		C	4.88**	4.56**			
		D	7.24**	9.40**	3.59**		
		E	57.48**	70.15**	56.52**	79.47**	
⋮							
18	Fosp	B	9.67**				18 38
		C	4.66**	4.79**			
		D	6.12**	8.14**	2.40*		
		E	72.67**	66.86**	55.72**	71.42**	
19	Mesc	B	8.96**				19 37
		C	4.62**	4.59**			
		D	5.79**	7.93**	3.22**		
		E	69.61**	63.99**	52.44**	70.52**	

*, **Significance of F values for separation of group means at .05 and .01 probability levels.

Figure 5. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Brushland (BR) data set.

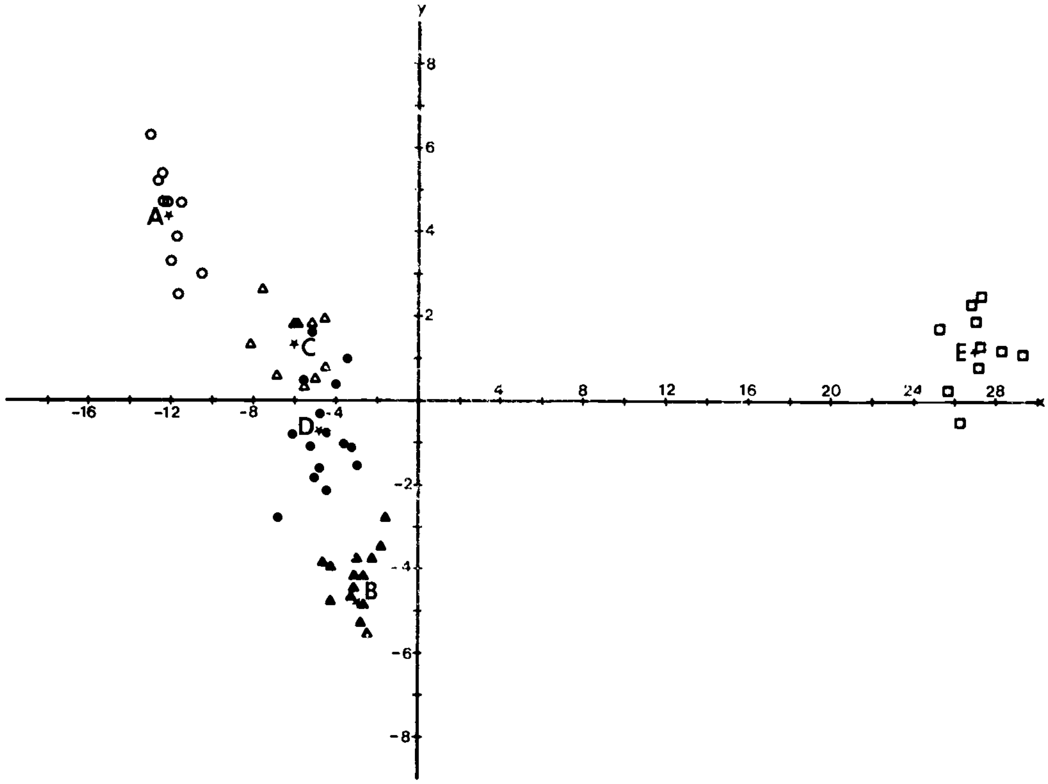
Groups A, B, C, and D correspond to Subassociations 2E, 2F, 2G, and 2H of Association B (Rhus microphylla-Dalea formosa). Group E corresponds to Association C (Gutierrezia sarothrae/Eriogonum abertianum).

*Indicates group means.

Figure 6. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Brushland (BR) data set.

Subgroups 1A, 1B; 2C, 2D; 3E, 3F; 4G and 4H correspond to unranked units of Subassociations 2H, 2F, 2G, 2H of Association B (Rhus microphylla-Dalea formosa). Subgroups 5I and 5J correspond to Subassociations 4G and 4H of Association C (Gutierrezia sarothrae/Eriogonum abertianum).

*Indicates subgroup means.


y
x
A
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E
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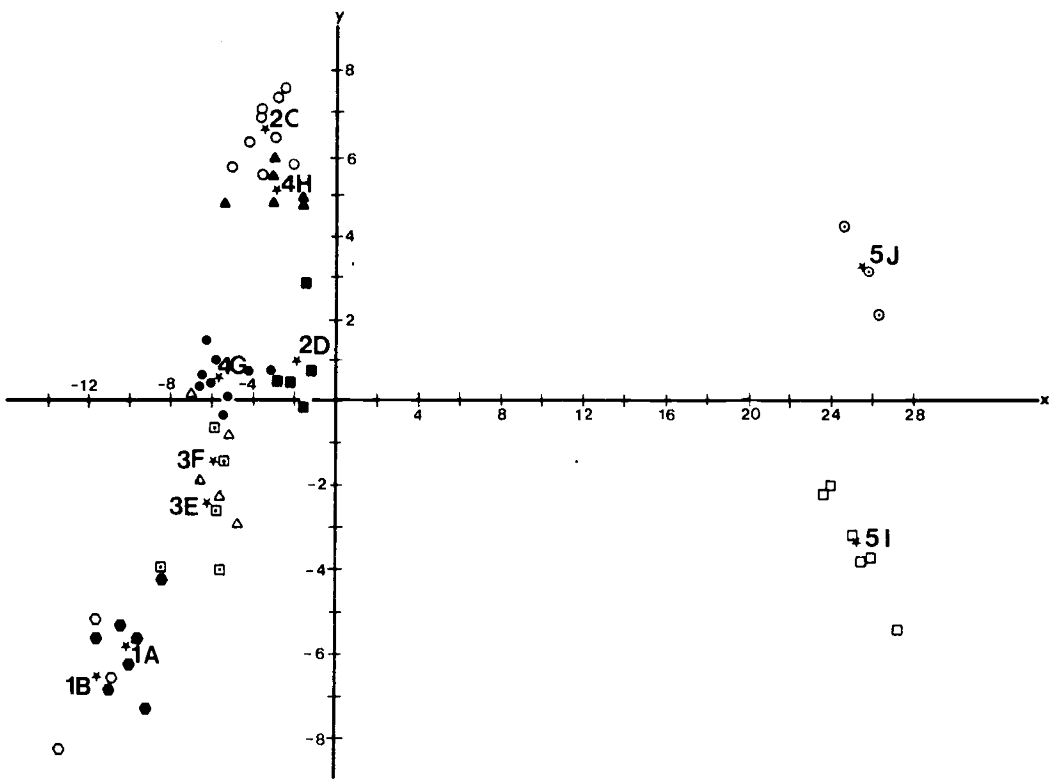
y
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1A
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2C
2D
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3F
4G
4H
5I
5J
-12
-8
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4
8
12
16
20
24
28
8
6
4
2
-2
-4
-6
-8

to achieve perfect discrimination. The first discriminant was the same as in level one; the second one, however, was different--*Aristida divaricata* (Ardi).

Significant pairwise separation of subgroup means at P = .01 was not attained at any one particular step although there was separation among certain subgroups as indicated in Table 16. The graph in Figure 6 represents the results of plotting the first versus the second canonical variable. Subgroup separation within associations is good for Association C (*Gutierrezia sarothrae*/*Eriogonum abertianum*) and almost nonexistent for Association B (*Rhus microphylla*-*Dalea formosa*).

The total dispersion figures have been mentioned in each group and subgroup that has been analyzed. However, in any previous group and subgroup the number of canonical variables contributing to the total dispersion were as many as in the present one--nine in total; the first and the second accounted for 76 and 85 percent. It is interesting to note in this unit that the difference between attributes used in both levels is minimal. This may give an indication about the validity of numbers as well as the size of subgroups considered in the second level. The results of this level indicate that the division of the number of stands per subgroups was too fine and did not correspond with the features as represented on the ground. Sokal and Sneath (1963) suggest that dendrograms of less than 10 OTU's (operational

Table 16. Values of the F matrix used to test the pairwise differences among subgroup means on the second hierarchical level of the Brushland (BR) data set.

Step	Species entered	Subgroup	1A	1B	2C	2D	3E	3F	4G	4H	5I	d.f.
1	Erab	1B	0									1 50
		2C	0	0								
		2D	0	0	0							
		3E	0	0	0	0						
		3F	0	0	0	0	0					
		4G	0	0	0	0	0	0				
		4H	1.92	1.19	2.14	1.62	1.62	1.62	2.14			
		5I	45.00**	26.29**	51.05**	37.08**	37.08**	37.08**	51.05**	25.00**		
		5J	45.00**	32.14**	48.21**	40.17**	40.17**	40.17**	48.21**	29.76**	2.92	
2	Ardi	1B	2.62									2 49
		2C	21.26**	3.26*								
		2D	15.75**	2.72	0							
		3E	15.75**	2.72	0	0						
		3F	15.75**	2.72	0	0	0					
		4G	14.54**	1.45	.72	.51	.51	.51				
		4H	18.87**	3.64*	1.05	.79	.79	.79	1.72			
		5I	28.74**	12.99**	29.11**	21.15**	21.15**	21.15**	26.45**	15.79**		
		5J	35.36**	18.68**	23.70**	19.75**	19.75**	19.75**	24.42**	14.63**	4.46*	
3	Dawh	1B	1.73									3 48
		2C	15.18**	3.15*								
		2D	10.78**	2.26	.08							
		3E	10.36**	1.91	.53	.14						
		3F	10.36**	1.91	.53	.14	0					
		4G	22.80**	9.39**	7.66**	6.88**	9.30**	9.30**				
		4H	13.21**	3.15*	.69	.55	.86	.86	7.35**			
		5I	19.13**	8.58**	22.33**	15.42**	14.52**	14.52**	36.85**	12.76**		
		5J	23.13**	12.20**	16.62**	13.46**	13.07**	13.07**	24.73**	10.42**	2.97*	

(Continued on next page)

Table 16. (Continued).

Step	Species entered	Subgroup	1A	1B	2C	2D	3E	3F	4G	4H	5I	d.f.
.												
.												
.												
33	Hodr	1B	1.85									33 18
		2C	6.87**	6.00**								
		2D	4.21**	4.07**	1.28							
		3E	2.05	2.10*	2.80*	1.91						
		3F	1.92	2.13*	2.99**	2.39*	.82					
		4G	5.15**	5.32**	3.84**	2.89**	2.62*	2.15*				
		4H	6.87**	4.50**	3.33**	2.93**	3.98**	2.84*	5.94**			
		5I	37.84**	25.57**	31.16**	21.12**	25.31**	24.12**	35.49**	22.95**		
		5J	25.20**	21.21**	17.32**	14.02**	17.77**	17.49**	19.30**	16.53**	3.73**	

*,** Significance of F values for separation of subgroups at .05 and .01 levels.

taxonomic units, stands here) need not be divided into more than four classes. The criteria followed in this study for group formation is one of having at least three stands per group; in only two instances groups of 10 and 12 stands were divided into subgroups of 7, 3, and 8 and 3 stands, respectively. The 8 and 3 stands per subgroup were separated; not so the 7 and 3, and even others having a larger sample size. Here, then, it is more a matter of the kind of data we are dealing with rather than the sample size.

The Dragoons (DR) Data Set

Three groups of 22, 24, and 20 stands each were analyzed at the first level in this set; they correspond to Subassociation 1A, 2C and part of Subassociation 2D on Table 7, respectively. Perfect discrimination among groups was obtained by the inclusion of 34 species out of a total of 36 used in the process. _Tridens muticus_ (Trmu), _Zinnia pumila_ (Zipu), and _Gomphrena caespitosa_ (Goca) are the three best discriminants in that order. Significance at the .01 probability among the group means on a pairwise fashion was obtained by the third best discriminant, _Gomphrena caespitosa_. No change in this level was observed by the inclusion of the rest of the species used in the operation (Table 17).

The first canonical variable was plotted against the second; the result is presented in Figure 7. The group separation is clear; all

Table 17. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of the Dragoons (DR) data set.

Step	Species entered	Group	A	B	d. f.
1	Trmu	B	31.77**		1 63
		C	46.07**	2.04	
2	Zipu	B	40.01**		2 62
		C	49.95**	1.27	
3	Goca	B	26.24**		3 61
		C	43.14**	11.50**	

**Significance of F values for separation of groups at .01 probability level.

the cases are around their respective means with the exception of a few "outliers" in group B and C. The total dispersion found in the analysis of this set of data is included in the first and second canonical variables.

At the second level, nine subgroups were considered with the number of stands ranging from 3 to 14 (14, 5, 3; 12, 4, 8; 11, 5, 4) having no definite rank within Subassociations 1A, 2C, and 2D, respectively (Table 18). All of the 41 species were used at this level and no perfect discrimination was achieved. Furthermore, the inclusion of the 41st species, Setaria macrostachya (Sema) did not improve the classification matrix as printed out at the 40th step; the same stand was misclassified in group 2F. The first and second best discriminants are Mollugo verticillata (Move) and Lycium pallidum (Lypa). Significance at .01 probability level of the pairwise difference

Table 18. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Dragoons (DR) data set.

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	2F	3G	3H	d. f.
1	Move	1B	0								1 57
		1C	0	0							
		2D	0	0	0						
		2E	.88	.63	.48	.85					
		2F	.36	.21	.15	.34	.18				
		3G	83.42**	46.55**	31.92**	77.72**	29.05**	54.97**			
		3H	0	0	0	0	.63	.21	46.55**		
		3I	7.94**	5.67*	4.37*	7.66**	2.26	4.72*	12.71**	5.67*	
2	Lypa	1B	0								2 56
		1C	7.10**	5.39**							
		2D	.29	.15	5.28**						
		2E	.49	.35	5.98**	.77					
		2F	23.89**	14.43**	.54	18.34**	14.12**				
		3G	42.35**	23.63**	26.75**	40.86**	14.60**	58.55**			
		3H	.95	.64	2.64	.31	1.23	8.47**	26.17**		
		3I	4.41*	3.15	9.72**	4.90*	1.26	19.85**	6.25**	4.64*	
3	Goca	1B	0								3 55
		1C	5.32**	4.04*							
		2D	.21	.11	3.96*						
		2E	.35	.25	4.59**	..60					
		2F	17.66**	10.67**	.38	13.54**	10.68**				
		3G	42.89**	23.93**	27.82**	42.08**	15.83**	60.75**			
		3H	1.75	1.19	3.89*	1.55	1.24	9.87**	20.68**		
		3I	30.64**	21.88**	27.46**	31.15**	17.40**	47.89**	9.99**	16.19**	

(Continued on next page)

Table 18. (Continued).

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	2F	3G	3H	d. f.
4	Trgr	1B	5.09**								4 54
		1C	8.50**	3.04*							
		1D	6.47**	.21	3.25*						
		2E	.29	3.85**	7.09**	4.05**					
		2F	23.15**	8.03**	.28	10.83**	14.03**				
		3G	38.51**	17.67**	20.70**	31.02**	15.66**	45.39**			
		3H	6.59**	.87	2.92*	1.30	4.72**	7.40**	15.29**		
		3I	25.69**	16.18**	20.44**	22.94**	15.28**	35.71**	7.36**	12.01**	
5	Gusa	1B	4.00**								5 53
		1C	6.71**	2.40*							
		1D	5.09**	.18	2.61*						
		2E	1.10	3.72**	6.29**	3.88**					
		2F	19.97**	7.50**	1.33	9.96**	11.03**				
		3G	32.48**	15.25**	17.48**	26.14**	12.31**	35.57**			
		3H	14.35**	7.15**	7.69**	9.32**	6.15**	8.79**	15.27**		
		3I	20.98**	13.35**	16.73**	18.66**	12.00**	28.05**	5.81**	11.96**	
6	Trmu	1B	3.28**								6 52
		1C	7.97**	3.72**							
		1D	5.00**	.70	6.60**						
		2E	3.05*	4.71**	10.92**	3.84**					
		2F	17.34**	6.84**	5.67**	8.17**	9.42**				
		3G	30.49**	14.86**	21.96**	22.48**	10.07**	29.66**			
		3H	13.49**	7.15**	11.66**	8.01**	5.07**	7.37**	12.53**		
		3I	19.28**	12.57**	19.42**	15.91**	9.81**	23.33**	4.75**	9.82**	

(Continued on next page)

Table 18. (Continued).

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	2F	3G	3H	d. f.
7	Zipu	1B	2.95*								7 51
		1C	7.25**	3.23**							
		1D	10.23**	2.48*	6.13**						
		2E	4.48**	4.63**	9.34**	3.33**					
		2F	21.26**	8.31**	5.75**	7.03**	8.26**				
		3G	34.06**	15.51**	19.60**	19.14**	8.90**	24.94**			
		3H	16.43**	8.24**	10.74**	6.89**	4.60**	6.20**	10.53**		
		3I	20.68**	12.64**	17.23**	13.54**	8.59**	19.62**	3.99**	8.26**	
8	Mibi	1B	2.56*								8 50
		1C	6.34**	2.95**							
		1D	8.98**	2.38*	5.26**						
		2E	7.30**	6.87**	9.20**	5.16**					
		2F	19.49**	8.18**	5.10**	6.51**	7.92**				
		3G	29.82**	13.85**	16.84**	16.52**	9.25**	21.55**			
		3H	18.62**	10.64**	10.68**	8.96**	3.95**	6.47**	11.21**		
		3I	17.74**	10.86**	14.86**	11.69**	9.54**	17.45**	3.69**	9.75**	
9	Chco 1	1B	3.15**								9 49
		1C	6.22**	4.57**							
		1D	9.23**	5.37**	4.59**						
		2E	7.51**	8.72**	8.03**	4.55**					
		2F	19.47**	11.56**	4.50**	5.93**	6.92**				
		3G	28.27**	16.31**	8.03**	14.51**	8.05**	18.81**			
		3H	18.57**	13.49**	4.59**	8.19**	3.52**	5.66**	9.89**		
		3I	16.43**	11.96**	12.94**	10.21**	8.31**	15.25**	3.22**	8.62**	

(Continued on next page)

Table 18. (Continued).

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	2F	3G	3H	d. f.
.											
.											
.											
41	Sema	1B	1.60								41 17
		1C	2.87*	3.88**							
		2D	6.90**	5.24**	2.46*						
		2E	4.08**	4.02**	2.92**	1.24					
		2F	8.19**	5.75**	2.69*	1.62	1.84				
		3G	17.58**	10.54**	7.30**	9.78**	5.00**	9.64**			
		3H	8.03**	6.90**	3.32**	1.80	1.31	1.96	5.81**		
		3I	8.64**	6.98**	5.40**	4.18**	3.71**	5.21**	4.33**	2.65	

*,** Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 7. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Dragoons (DR) data set.

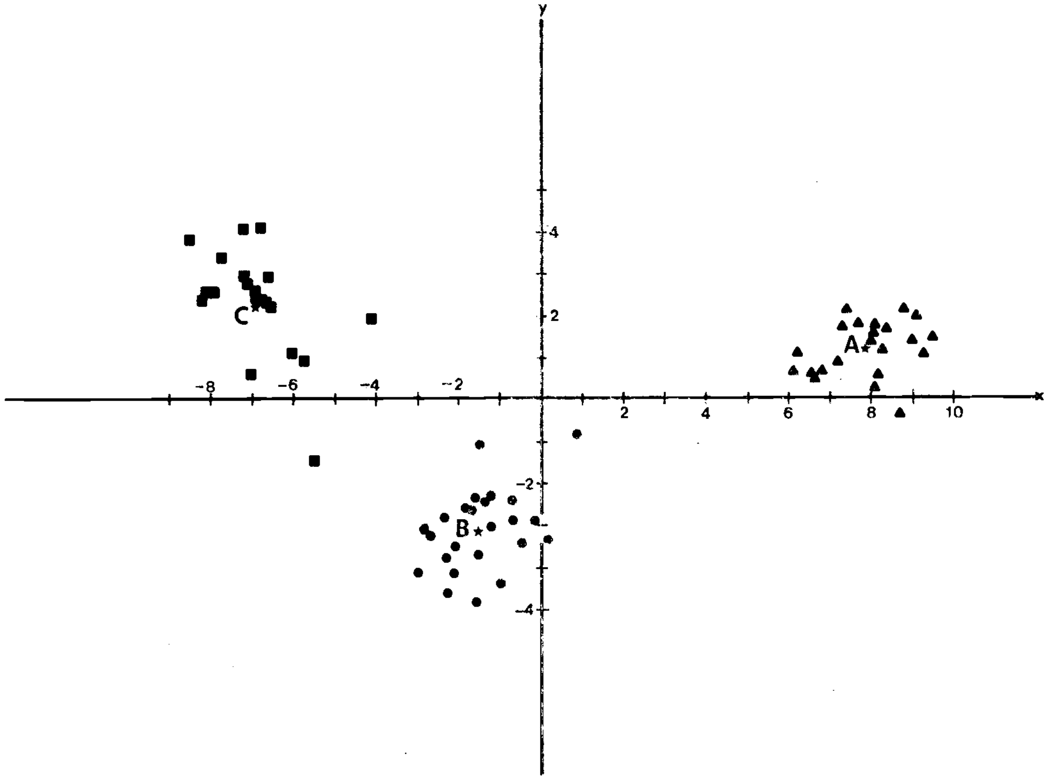
Group A corresponds to Subassociation 1A of Association D (Menodora scabra/Tridens grandiflorus); B and C correspond to Subassociation 2C and part of Subassociation 2D of Association E (Hilaria belangeri).

*Indicates the group means.

Figure 8. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Dragoons (DR) data set.

Subgroups 1A, 1B, 1C; 2D, 2E, 2F; 3G, 3H, and 3I are unranked units corresponding to Subassociation 1A; 2C, and 2D of Association D (Menodora scabra/Tridens grandiflorus), and Association E (Hilaria belangeri), respectively.

*Indicates the subgroup means.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B
C
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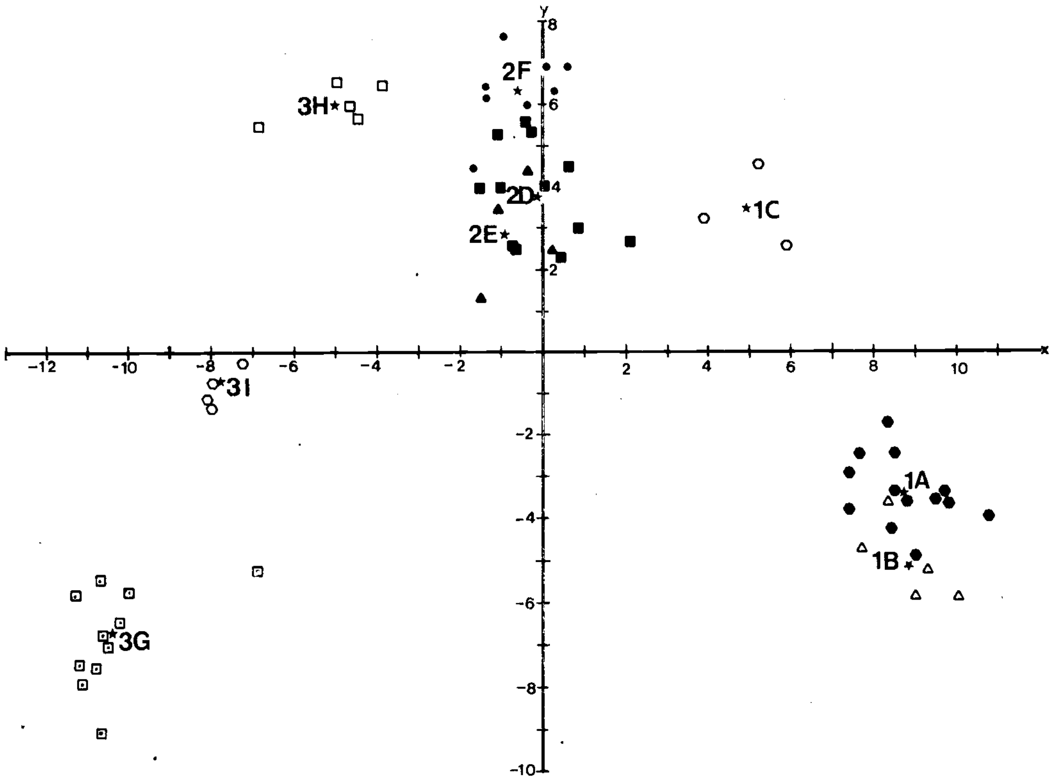
-6
-4
-2
2
4
6
8
10
4
2
-2
-4


y
x
2F
3H
2D
2E
1C
3I
1A
1B
3G
-12
-10
-8
-6
-4
-2
2
4
6
8
10
8
6
4
2
-2
-4
-6
-8
-10

among subgroup means was obtained at the ninth step when Chamaesaracha coniodes (Chco 1) entered (Table 18). After this step the significance fluctuated according to the species entered at a given step. In most of the subgroups, it was maintained at .01, .05 in others, and no significance in the rest. The reason for this behavior is that none of the species entering into the process after the ninth step had an F-value large enough so as to increase the significance level among the group means back to the .01 probability level.

Figure 8 results from plotting the first versus the second canonical variates; a better insight is gained about the possible causes of the lack of separation among certain subgroups. Note that a few of them are well differentiated, others (1A, 1B; 2D, 2E, and 2F) are so close to each other that they appear to form a subgroup by themselves instead of having to be divided further. In the way they are shown, it is difficult to separate them on two dimensions. It should be remembered that in cases like this and others already discussed, the difficulty in separating subgroups stems from the fact that some dispersion is left unaccounted for when only the first two canonical variables are plotted. In this case the first eight canonical variables accounted for the total dispersion, the first and second accounted for only 49 and 74 percent, respectively.

The Andesite Hills (AH) Data Set

Three groups at the first level with 30, 14, and 14 stands each representing Association K (typical association), Subassociation 1A, and Subassociation 1B of Association L (Agave palmeri-Agave parryi/Haplopappus laricifolius) were tested in this data set. Twenty-eight out of 30 species were required to obtain a perfect discrimination. The number of species required to reach this point reflects that some of the groups may be closely related to each other. However, if the values of the F matrix used to test the difference among the groups means are observed, significance at .01 probability level is shown by the inclusion of Brickellia venosa (Brve) and Bouteloua hirsuta (Bohi), first and second best discriminants, respectively (Table 19). The inclusion of the rest of the species required to achieve the perfect discrimination did not affect the significance.

Table 19. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of the Andesite Hills (AH) data set.

Step	Species entered	Group	A	B	d. f.
1	Brve	B	.13		1 55
		C	34.58**	28.60**	
2	Bohi	B	14.10**		2 54
		C	18.42**	18.79**	

**Significance of F values for separation of group means at .01 probability level.

These results raise the question as to whether it would be possible to obtain a good group separation by stopping the SDA after step two instead of after the 30th step and do the canonical analysis on the basis of those attributes. Undoubtedly this can be done but in all probability, the groups would not be as well separated as when all the species are included. Mention was made in the previous paragraphs about the close relationship of groups; however, by looking at the results of plotting the first two canonical variables (Figure 9), the groups appear to be well defined with no overlapping at all, which somewhat contradicts previous statements regarding one of the possible reasons for having so many variables in the SDA. However, if these groups are projected from their two dimensional positions to one plane, undoubtedly there would be some overlapping among groups A and B because of the presence of some "outliers" in both cases. The total dispersion was accounted for by the first two canonical variables (79 and 100 percent, respectively).

At the second level seven subgroups (18, 6, 6; 9, 5; 7, and 7 stands) were considered. These subgroups represent Subassociations 3E, 3F, and 3G of Association K (typical association), and other lower rank units of Subassociations 1A and 1B of Association L (Agave palmeri-Agave parryi/Haplopappus laricifolius). Twenty-four species were used in the SDA, 23 of those were required to achieve a perfect discrimination. Prosopis juliflora (Prju) is the best discriminant and Brickellia venosa (Brve) is the second best.

The pairwise differences among subgroup means show a pattern different from those already mentioned. Significance at .01 probability level was reached at the 19th step by the inclusion of *Parthenium incanum* (Pain). Several species [*Gutierrezia sarothrae* (Gusa), *Desmanthus cooleyi* (Deco), *Dasylirium wheeleri* (Dawh), *Heteropogon contortus* (Heco), and *Trachypogon montufari* (Trmo)] entered the process after this last step; only *Gutierrezia sarothrae* and *Dasylirium wheeleri* maintained the significance at .01. The entrance of the rest of the species at a specified step dropped the probability level of the pairwise difference between subgroup means 1A and 1B, and 1B and 2D to .05 (Table 20).

Figure 10 illustrates the results of plotting the first versus the second canonical variable. It appears from the graph that there is some overlapping between subgroups 1A, 1B, and 2D which may suggest those subgroups should be considered as one. The rest of the subgroups appear to be well differentiated.

A better subgroup separation could be achieved if there were some way to portray the first six canonical variables on a graph since these variables account for the total dispersion; however, such a graph would be difficult to visualize. It is true that in two dimensions where the first and second canonical variable accounts for .47 and .79 percent, respectively, subgroups 1A, 1B, and 2D are difficult to separate. By increasing the dimensions, the separation among those subgroups could be improved somewhat.

Table 20. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Andesite Hills (AH) data set.

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	3F	d. f.
1	Prju	1B	.03						1 51
		1C	23.48**	16.91**					
		2D	.56	.56	14.09**				
		2E	35.64**	26.34**	1.46	23.64**			
		3F	.27	.33	13.58**	.02	22.61**		
		3G	.39	.44	12.97**	.002	21.86**	.007	
2	Brve	1B	.81						2 50
		1C	11.52**	8.94**					
		2D	.27	.93	6.91**				
		2E	17.48**	13.54**	.72	11.60**			
		3F	5.90**	1.53	10.69**	4.57*	14.82**		
		3G	16.27**	6.24**	17.21**	12.65**	20.67**	1.79	
3	Yuel	1B	.58						3 49
		1C	18.70**	14.40**					
		2D	2.14	2.30	8.14**				
		2E	11.53**	8.85**	8.79**	9.35**			
		3F	3.93*	1.00	16.26**	4.86**	9.69**		
		3G	10.70**	4.08*	20.53**	10.14**	13.51**	1.17	
⋮									
19	Pain	1B	3.25**						19 33
		1C	11.15**	6.06**					
		2D	3.64**	2.81**	5.48**				
		2E	11.97**	9.63**	10.69**	12.77**			
		3F	9.63**	5.64**	12.62**	9.06**	6.68**		
		3G	17.61**	12.81**	21.07**	16.66**	5.89**	4.33**	

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Table 20. (Continued).

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	3F	d. f.
20	Gusa	1B	3.01**						20 32
		1C	11.21**	6.33**					
		2D	3.35**	2.61**	5.76**				
		2E	13.54**	10.87**	15.70**	13.77**			
		3F	8.98**	5.33**	11.93**	8.42**	7.39**		
		3G	16.81**	12.31**	19.45**	15.77**	6.04**	4.12**	
21	Deco	1B	2.79**						21 31
		1C	15.17**	8.66**					
		2D	3.39**	2.50*	7.68**				
		2E	15.34**	11.72**	14.58**	13.97**			
		3F	8.40**	4.94**	13.55**	7.79**	8.27**		
		3G	15.71**	11.41**	20.22**	14.56**	6.83**	3.81**	
22	Dawh	1B	2.67**						22 30
		1C	17.47**	9.62**					
		2D	4.59**	2.75**	7.62**				
		2E	14.17**	10.90**	15.66**	13.76**			
		3F	7.94**	4.57**	14.02**	7.55**	7.77**		
		3G	14.83**	11.04**	22.79**	15.64**	6.46**	4.21**	
23	Heco	1B	2.49*						23 29
		1C	18.01**	9.90**					
		2D	4.69**	2.70**	7.54**				
		2E	14.63**	10.93**	14.48**	13.12**			
		3F	7.90**	4.46**	13.28**	7.00**	7.44**		
		3G	16.38**	11.63**	21.09**	15.27**	6.01**	4.44**	

(Continued on next page)

Table 20. (Continued).

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	3F	d. f.
24	Trmo	1B	2.60**						24 28
		1C	17.43**	9.23**					
		2D	4.80**	2.50*	7.04**				
		2E	15.67**	10.75**	13.69**	12.83**			
		3F	7.47**	4.14**	12.46**	6.51**	7.79**		
		3G	10.55**	11.00**	19.56**	14.38**	5.69**	4.53**	

*, **Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 9. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Andesite Hills (AH) data set.

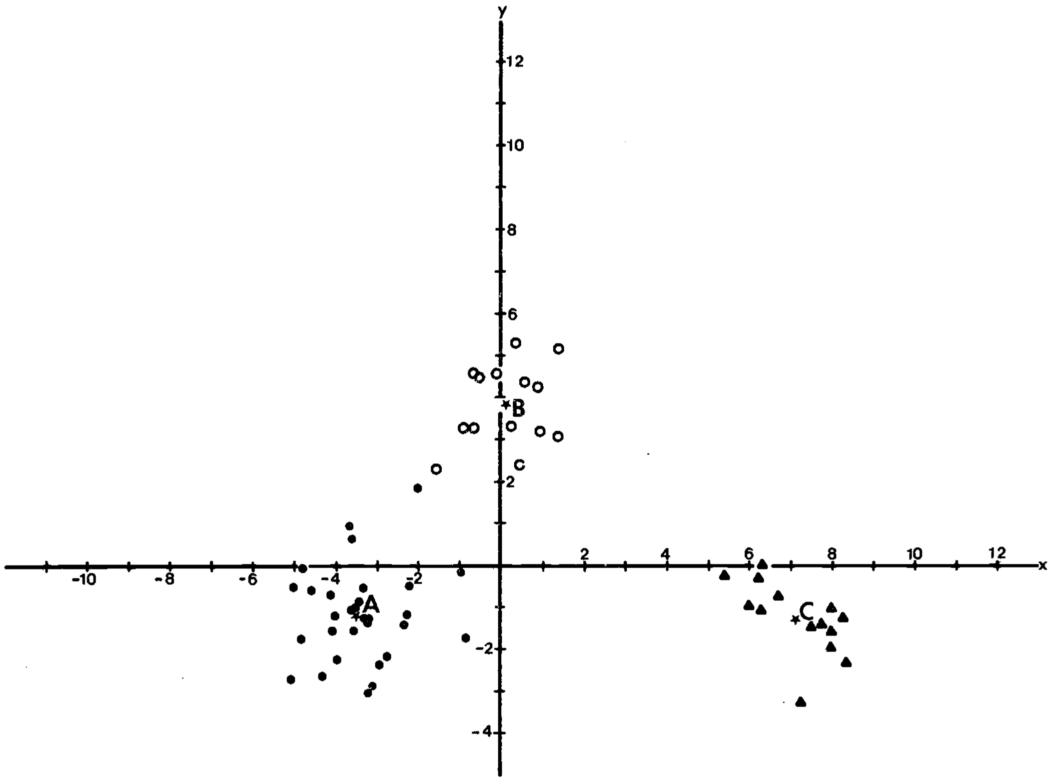
Groups A, B, and C represent Association K (typical association) and Subassociations 1A and 1B of Association L (*Agave palmeri*-*A. parryi*/*Haplopappus laricifolius*).

*Indicates the group means.

Figure 10. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Andesite Hills (AH) data set.

Subgroups 1A, 1B, 1C; 2D, 2E, 3F and 3G correspond to Subassociations 3E, 3F, and 3G; and other lower rank units of Subassociations 1A and 1B of Association K (typical association), and Association L (*Agave palmeri*-*A. parryi*/*Haplopappus laricifolius*), respectively.

*Indicates the subgroup means.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6
2
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4
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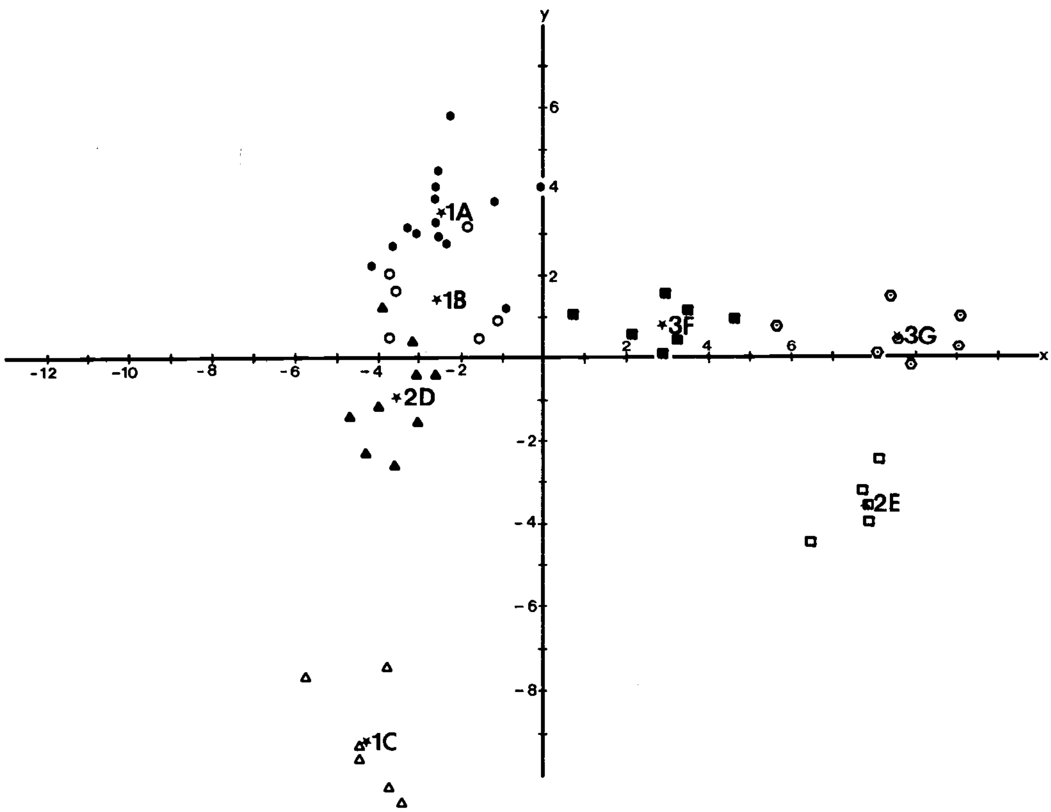
12
A
B
C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4
6
1A
1B
1C
2D
2E
3F
3G

The Mule Mountains (MU) Data Set

The first hierarchical level of the MU data set was subject to the stepwise discriminant analysis. It has three groups with 16; 13, and 13 stands each. The former corresponds to Association H (Haplopappus tenuisectus/Eragrostis lehmanniana) and the Variant 1a; the other two correspond to Subassociations 2C and 2D of Association I (Ayenia pusilla/Eragrostis intermedia).

Twelve species were used in the SDA, 10 of them were required to achieve a perfect discrimination. Eysenhardtia polystachya (Eypo) was the best discriminant, Fouquieria splendens (Fosp) was the second best. This latter species caused a separation among group means at a .01 probability level (Table 21). The graph (Figure 11) showing the results of plotting the first versus the second canonical variate indicates a good group separation, group A being the most homogeneous whereas C is the one having the greatest within group dispersion. The first and second canonical variables accounted for the total dispersion--the first accounting for 79 percent and the second 100 percent.

At the second level in the MU data set, seven subgroups having 5; 6, 5; 8, 5; 7, and 6 stands each were used. The subgroups are identified with the Variant 1a, Subassociation 1A of Association H (Haplopappus tenuisectus/Eragrostis lehmanniana), and Subassociations

Table 21. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of the Mule Mountains (MU) data set.

Step	Species entered	Group	A	B	d. f.
1	Eypo	B	1.41		1 39
		C	59.61**	38.68**	
2	Fosp	B	13.46**		2 38
		C	29.87**	25.27**	

**Significance of F values for separation of groups at .01 probability level.

2C and 2D of Association I (Ayenia pusilla/Eragrostis intermedia). The same 12 species used in the SDA were required to achieve a perfect discrimination. Sanvitalia abertii(Saab) was the best discriminant and Dasylirium wheelerii (Dawh) the second best. The significance at .01 probability level when the subgroups were compared in a pairwise fashion was obtained when Perezia nana (Pena) entered the process at the twelfth step (Table 22). When the first canonical variable was plotted versus the second, only subgroups 1A, 3F, and 2G were standing by themselves; the rest of the subgroups overlap somewhat (Figure 12). The total dispersion is accounted by the first six canonical variables, the first and the second accounting for 60 and 77 percent only.

The Kendall Ranch and Tobosa Bottoms (KR) Data Set

This set has three phytosociological taxa, two with 12 stands

Table 22. Values of the F-matrix used to test the differences among the subgroup means on the second hierarchical level of the Mule Mountains (MU) data set.

Step	Species entered	Subgroup	1A	1B	1C	2D	2E	3F	d. f.
1	Saab	1B	10.22**						1 35
		1C	37.50**	10.22*					
		2D	46.15**	12.85**	0				
		2E	37.50**	10.22**	0	0			
		3F	43.75**	12.11**	0	0	0		
		3G	28.40**	5.00*	1.13	1.42	1.13	1.34	
2	Dawh	1B	4.98*						2 34
		1C	18.35**	5.04*					
		2D	22.18**	6.27**	.20				
		2E	18.35**	5.05*	0	.20			
		3F	36.34**	23.75**	18.45**	19.00**	18.45**		
		3G	13.94**	2.71	1.15	.84	1.15	14.14**	
⋮									
12	Pena	1B	21.83**						12 24
		1C	31.53**	4.45**					
		2D	29.24**	4.65**	5.04**				
		2E	24.49**	3.63**	5.16**	4.07**			
		3F	60.00**	22.48**	17.20**	17.03**	19.23**		
		3G	36.05**	12.42**	12.29**	6.56**	10.30**	18.51**	

*, ** Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 11. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Mule Mountains (MU) data set.

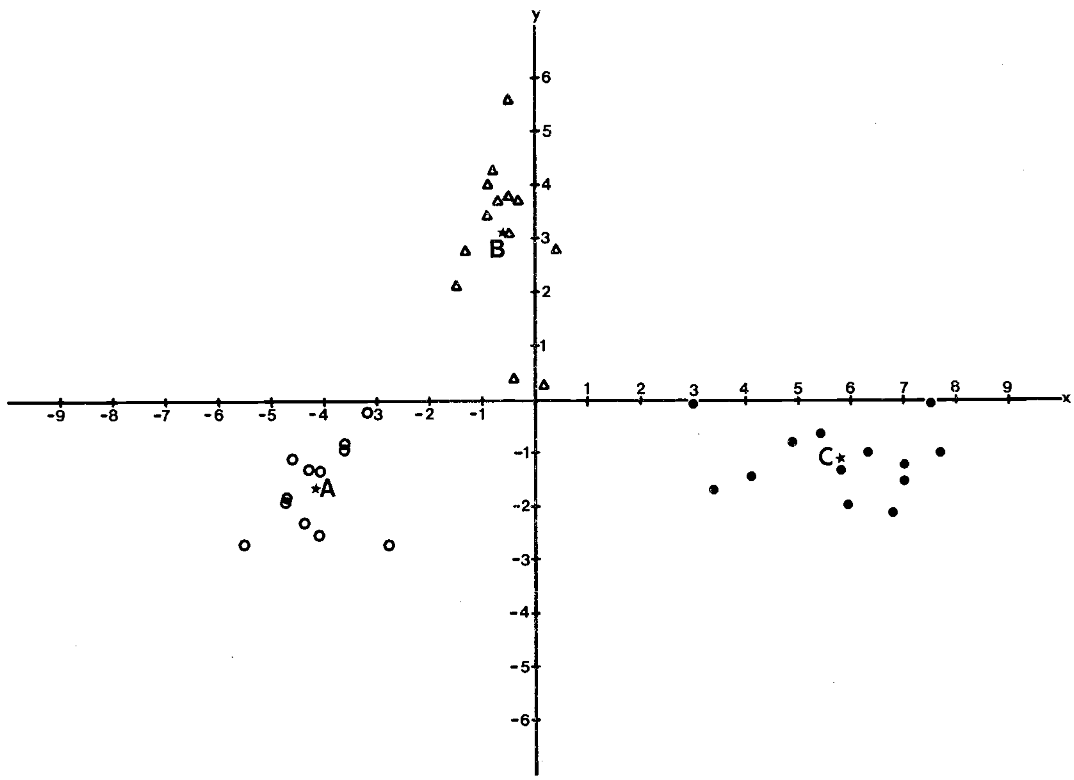
Group A corresponds to Subassociation 1A of Association H (Haplopappus tenuisectus/Eragrostis lehmanniana), and Variant 1a; Groups B and C correspond to Subassociations 2C and 2D of Association I (Ayenia pusilla/Eragrostis intermedia).

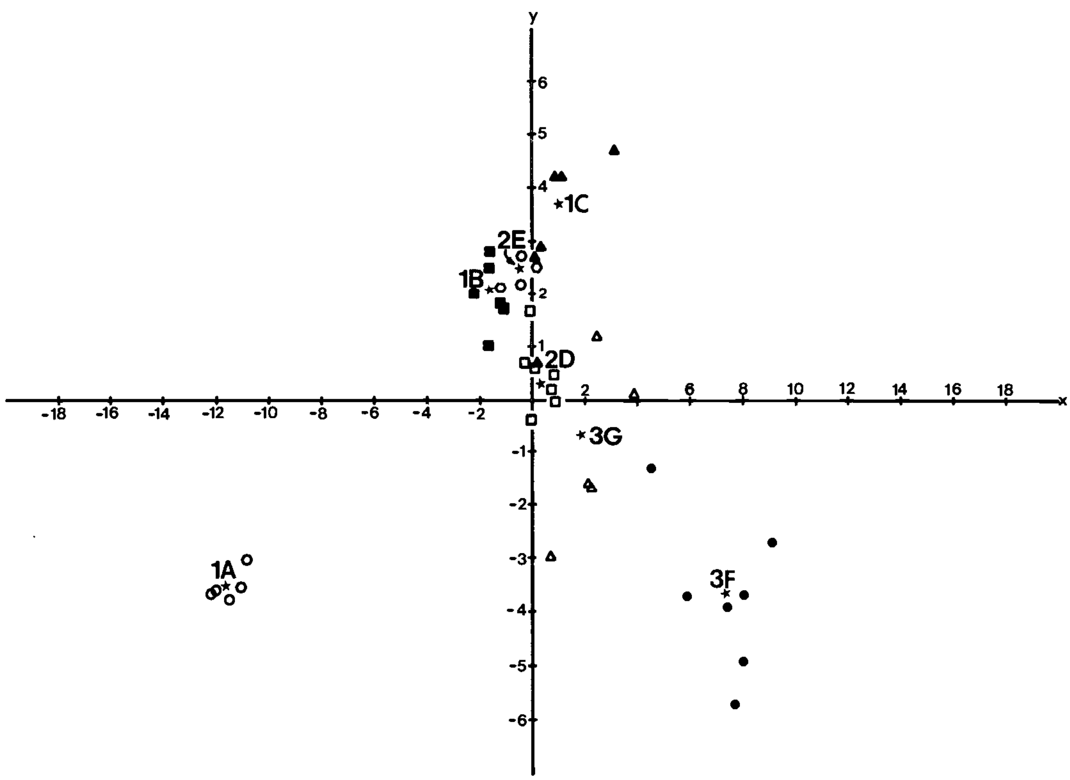
*Indicates group means.

Figure 12. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Mule Mountains (MU) data set.

Subgroup 1A corresponds to Variant 1a. Subgroups 1B, 1C; 2D, 2E; 3G and 3F correspond to Subassociations 1A, 2C, and 2D of Association H (Haplopappus tenuisectus/Eragrostis lehmanniana), and Association I (Ayenia pusilla/Eragrostis intermedia), respectively.

*Indicates subgroup means.


y
x
A
B
C


y
x
1A
1B
1C
2D
2E
3F
3G

each and one with 16. The first taxa having 12 stands corresponds to Association G (Hilaria mutica/Eriochloa gracilis/Crotalaria pumila). The group having 12 stands was incorporated as part of Subassociation 2D of Association E (Hilaria belangeri) and the group having 16 stands corresponds to Subassociation 1B of Association D (Menodora scabra/Tridens grandiflorus). At the first level, six species were used in SDA and also those same ones were required to obtain a perfect discrimination. Eriogonum wrightii (Erwr) and Bouteloua eriopoda (Boer) were the first and second best discriminants. Adding the latter species increased the probability to .01 among the pairwise differences of group means (Table 23).

Table 23. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of Kendall Ranch and Tobosa Bottoms (KR) data set.

Step	Species entered	Group	A	B	d. f.
1	Erwr	B	100.60**		1 37
		C	.53	99.83**	
2	Boer	B	51.99**		2 36
		C	28.20**	99.73**	

**Significance of F values for separation of groups at the .01 probability level.

The results of plotting the first two canonical variables are presented in Figure 13. The groups are well defined. Note also a great deal of dispersion within groups A and C, B being more homogeneous. In this case, the first and the second canonical variables account for the total dispersion, 65 and 100 percent, respectively.

At the second level, six subgroups of 7, 5; 7, 5; 9, and 7 stands each were considered. The first two correspond to Subassociations 1A and 1B of Association G (Hilaria mutica/Eriochloa gracilis/ Crotalaria pumila); the remainder of the subgroups correspond to lower rank units of Subassociation 2D of Association E (Hilaria belangeri) and Subassociation 1B of Association D (Menodora scabra/ Tridens grandiflorus), respectively. To achieve a perfect discrimination, eight out of 12 species were required. The first best discriminant was Eriogonum wrightii (Erwr) as in the first level. The second was Euphorbia serpyllifolia (Euse 1). Bouteloua eriopoda (Boer) was the third best discriminant. Significance at P = .01 was obtained when Aristida glauca (Argl 1) entered the process at the eighth step (Table 24).

The subgroups resulting from plotting the first versus the second canonical variables are presented in Figure 14. They are well dispersed showing little or no relationship with each other. Three of them (1A, 3E, and 3F) appeared to have a great deal of within dispersion. The total amount of dispersion is contained within the first five canonical variables; the first and second accounting for 74 and 88 percent, respectively.

Table 24. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Kendall Ranch and Tobosa Bottoms (KR) data set.

Step	Species entered	Subgroup	1A	1B	2C	2D	3E	d. f.
1	Erwr	1B	0					1 34
		2C	51.0 **	42.50**				
		2D	57.84**	49.58**	1.18			
		3E	0	0	57.37**	63.75**		
		3F	1.41	1.18	35.41**	42.50**	1.59	
2	Euse 1	1B	39.27**					2 33
		2C	28.77**	40.29**				
		2D	29.48**	46.18**	.98			
		3E	0	43.28**	32.37**	32.48**		
		3F	.72	37.74**	20.50**	21.65**	.81	
3	Boer	1B	25.58**					3 32
		2C	18.85**	26.88**				
		2D	19.60**	31.06**	.71			
		3E	8.75**	32.83**	33.15**	32.92**		
		3F	17.08**	35.11**	34.26**	33.92**	2.38	
4	Arwr	1B	19.39**					4 31
		2C	13.93**	19.73**				
		2D	14.33**	22.89**	.54			
		3E	35.93**	39.62**	48.33**	45.17**		
		3F	42.22**	42.22**	49.65**	46.69**	1.85	

(Continued on next page)

Table 24. (Continued)

Step	Species entered	Subgroup	1A	1B	2C	2D	3E	d. f.
5	Goca	1B	15.42**					5 30
		2C	21.17**	20.59**				
		2D	11.09**	18.11**	9.31**			
		3E	27.96**	30.78**	46.61**	35.12**		
		3F	33.03**	32.70**	45.40**	36.48**	1.49	
6	Crpu	1B	37.50**					6 29
		2C	19.24**	29.95**				
		2D	8.93**	35.82**	9.24**			
		3E	24.71**	68.28**	46.85**	30.17**		
		3F	28.61**	66.03**	44.96**	31.14**	1.20	
7	Crco	1B	31.03**					7 28
		2C	17.44**	25.99**				
		2D	7.45**	29.68**	8.41**			
		3E	35.06**	68.23**	45.11**	35.16**		
		3F	29.04**	59.00**	38.39**	29.25**	2.86*	
8	Argl 1	1B	26.21**					8 27
		2C	15.48**	22.85**				
		2D	6.29**	25.07**	7.71**			
		3E	55.56**	80.39**	55.45**	50.69**		
		3F	30.38**	55.43**	34.79**	29.49**	8.79**	

*, **Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 13. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Kendall Ranch and Tobosa Bottoms (KR) data set.

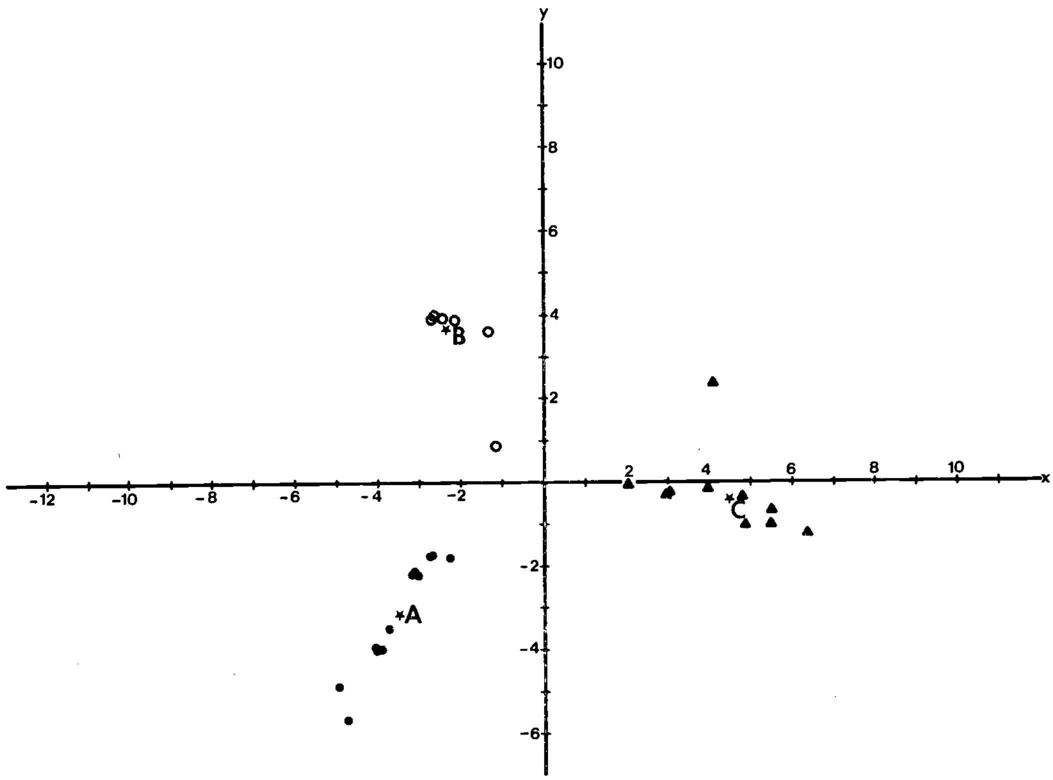
Group A represents Association G (*Hilaria mutica*/*Eriochloa gracilis*/*Crotalaria pumila*), Group B represents part of Subassociation 2D of Association E (*Hilaria belangeri*), and Group C represents Subassociation 1B of Association D (*Mendora scabra*/*Tridens grandiflorus*).

*Indicates the group means.

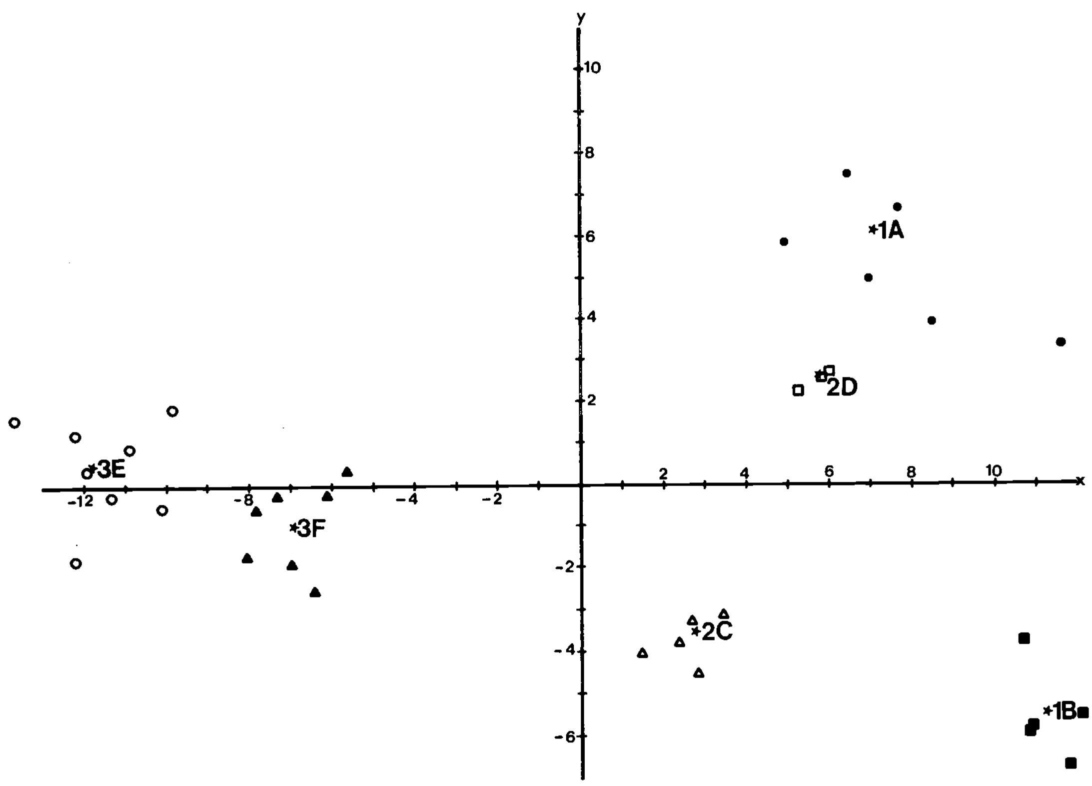
Figure 14. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Kendall Ranch and the Tobosa Bottoms (KR) data set.

Subgroups 1A, 1B; 2C, 2D; 3E and 3F correspond to Subassociations 1A and 1B, and lower rank units of Subassociations 2D, and 1B of Association G (*Hilaria mutica*/*Eriochloa gracilis*/*Crotalaria pumila*), Association E (*Hilaria belangeri*), and Association D (*Menodora scabra*/*Tridens grandiflorus*), respectively.

*Indicates the subgroup means.



y
x
*A
*B
*C



y
x
*1A
*1B
*2C
*2D
*3E
*3F

The Grassland (GR) Data Set

Two groups with 16 and 13 stands each at level one corresponding to Association F (Gilia rigidula-Rhynchosia texana) and Association H (Haplopappus tenuisectus/Eragrostis lehmanniana) were tested in this group. Three species out of 27 were used to attain a perfect discrimination. Cassia bauhinioides (Caba) is the best discriminant, Ephedra trifurca (Eptr) the second, and Gilia rigidula (Giri) the third. At step 12, however, the best discriminant was eliminated from the process. The same is true for Bouteloua rothrockii (Boro) which was entered at step 14 and eliminated at step 22. As can be appreciated, these two eliminations occurred after the perfect discrimination was attained. The only explanation for those removals is that the entrance of the new species in subsequent steps caused the decrease in the F-value of those species (Giri and Boro) to the point of insignificance.

Cassia bauhinioides by itself separated the two group means at P = .01. In Figure 15 where the first two canonical variables are plotted, the two groups are well differentiated. The mean group coordinates, however, have the same (y) = 0 values whereas the (x) values are different. A possible reason will be given when level one of the Tombstone Hills and Limestone Hills data sets (p. 137

and 140) will be discussed; the cumulative proportion of total dispersion is accounted for by the first canonical variate as well.

The second level of the Grassland (GR) data set was divided into four subgroups having 7, 9, 9, and 4 stands each. The former corresponds to Subassociations 3E and 3F of Association F (Gilia rigidula-Rhynchosia texana) and the latter corresponds to Subassociation 1B of Association H (Haplopappus tenuisectus/Eragrostis lehmanniana). Nine species out of 25 were used to attain a perfect discrimination among subgroups (no species was eliminated in the process as occurred in the first level).

As in the first level, Cassia bauhinioides was the best discriminant followed by Sporobolus cryptandrus (Spcr) rather than Ephedra trifurca which in turn was the third best discriminant. When testing pairwise differences among subgroup means, significance at P = .01 was reached by the inclusion of Yucca elata at the ninth step (Table 25).

The results of plotting the first two canonical variables are presented in Figure 16. A good separation of subgroups is observed. The first three canonical variables accounted for the total proportion of dispersion; the first and second accounting for .98 percent and .99 percent, respectively.

Table 25. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Grassland (GR) data set.

Step	Species entered	Subgroup	1A	1B	2C	d.f.
1	Caba	1B	5.46*			1 25
		2C	49.21**	25.00**		
		2D	31.81**	15.38**	.0	
2	Spcr	1B	9.46**			2 24
		2C	28.99**	12.10**		
		2D	19.69**	7.38**	.06	
3	Eptr	1B	6.84**			3 23
		2C	27.91**	13.12**		
		2D	18.60**	7.99**	.03	
4	Giri	1B	7.95**			4 22
		2C	20.75**	16.46**		
		2D	13.65**	9.93**	.02	
5	Paha	1B	10.05**			5 21
		2C	15.89**	19.26**		
		2D	10.53**	11.64**	.02	
6	Erle	1B	9.22**			6 20
		2C	12.84**	18.21**		
		2D	8.90**	9.27**	1.39	
7	Crco	1B	9.25**			7 19
		2C	11.44**	28.07**		
		2D	6.53**	9.54**	2.74*	
8	Ende	1B	8.80**			8 18
		2C	13.48**	28.07**		
		2D	6.53**	9.54**	2.74*	
9	Yuel	1B	9.07**			9 17
		2C	12.13**	29.12**		
		2D	6.82**	8.03**	6.16**	

*, ** Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 15. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Grassland (GR) data set.

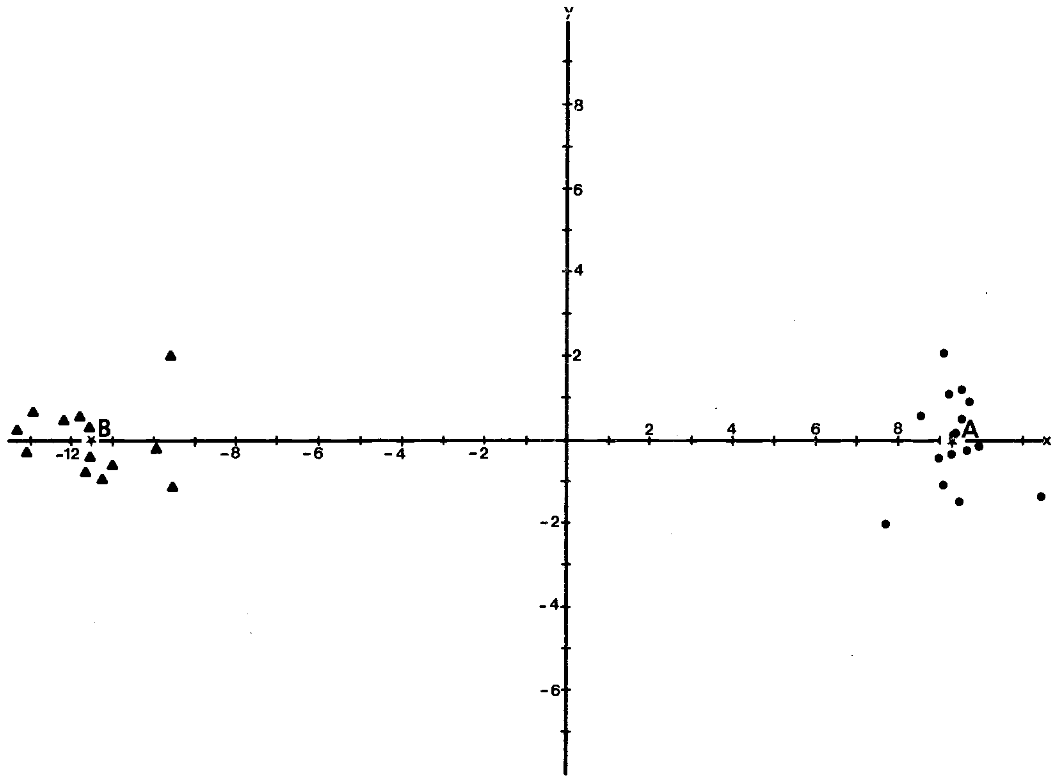
Group A corresponds to Association F (Gilia rigidula-Rhynchosia texana), and group B corresponds to Sub-association 1B of Association H (Haplopappus tenuisectus/Eragrostis lehmanniana).

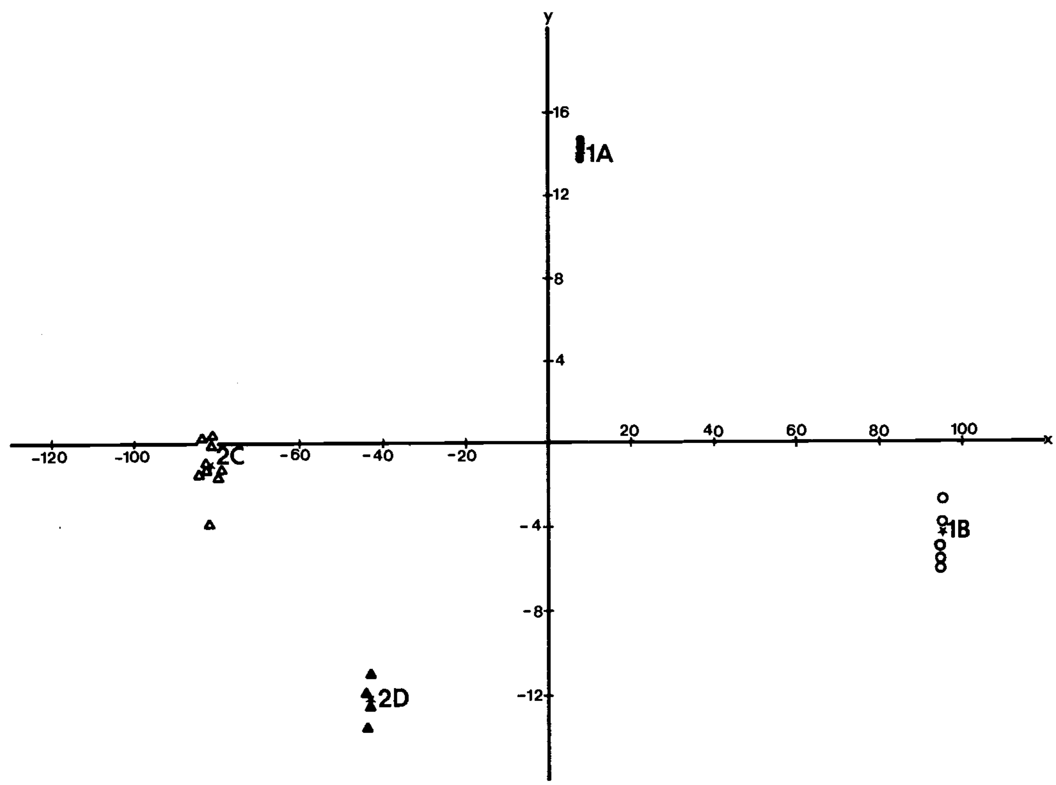
*Indicates the group means.

Figure 16. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Grassland (GR) data set.

Subgroup 1A, 1B; 2C and 2D correspond to Association F (Gilia rigidula-Rhynchosia texana), and to Association H (Haplopappus tenuisectus/Eragrostis lehmanniana), respectively.

*Indicates the subgroup means.


y
8
6
4
2
-2
-4
-6
x
2
4
6
8
-12
-8
-6
-4
-2
A
B


y
16
12
8
4
-4
-8
-12
x
20
40
60
80
100
-120
-100
-60
-40
-20
1A
1B
2C
2D

The Tombstone Hills (TH) Data Set

The Tombstone Hills data set has two phytosociological taxa well represented by the classification analysis, one taxon has 20 and the other has six stands at the first hierarchical level; the former corresponds to Subassociation 1A and the latter corresponds to Subassociation 1B, both belonging to Association J (Cnidoscolus angustidens). To confirm the discriminating value of those species which appear to identify them a stepwise discriminant analysis was performed. Out of six species selected to carry on the process, only four were required to achieve a perfect discrimination. The species were entered according to their discriminating power, that is, Hibiscus coulteri (Hico) was the best discriminant, Muhlenbergia arizonica (Muar 2) was the second best and so on. Furthermore, Hibiscus coulteri was the only attribute necessary to show the pairwise differences between groups A and B at .01 probability level.

From Figure 17it can be observed that the groups resulting from plotting the first two canonical variables are quite apart from each other. The means for both groups have the same (y) coordinate value (0) although the (x) coordinate values are different. These results are related to how the program works in the case of two groups of different size where the (x) coordinate of the first canonical variable with the larger sample size is closer to the origin than the one having a smaller sample size. Also, as in previous groups, zero value implies the absence of the second canonical variable, or its value is infinitely small. Thus, the dispersion is expressed wholly by the first canonical variable. It has a value of 1.

On the second level three subgroups (1A, 2B, and 2C) having 6, 16, and 4 stands per subgroup were included. Subgroup 1A corresponds to Subassociation A; 2B and 2C correspond to Subassociation B. All belong to Association J (Cnidoscolus angustidens). The six variables used in the SDA were the same required to achieve a perfect discrimination. In this case, Aristida adscensionis (Arad) became the best discriminant, Agave parryi (Agpa) the second, and Hibiscus coulteri (Hico) the third.

The significance at .01 probability level of the pairwise comparison among subgroup means was obtained by the inclusion of Hibiscus coulteri (Hico) on the third step (Table 26).

Table 26. Values of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Tombstone Hills (TH) data set.

Step	Species entered	Sub-group	1A	2B	d. f.
1	Arad	2B	.05172		1 23
		2C	29.12792**	41.30247**	
2	Agpa	2B	.20340		2 22
		2C	50.58417**	63.69470**	
3	Hico	2B	6.15886**		3 21
		2C	47.37312**	46.27672**	

**Significance of F values for separation of subgroups at .01 probability level.

Figure 17. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Tombstone Hills (TH) data set.

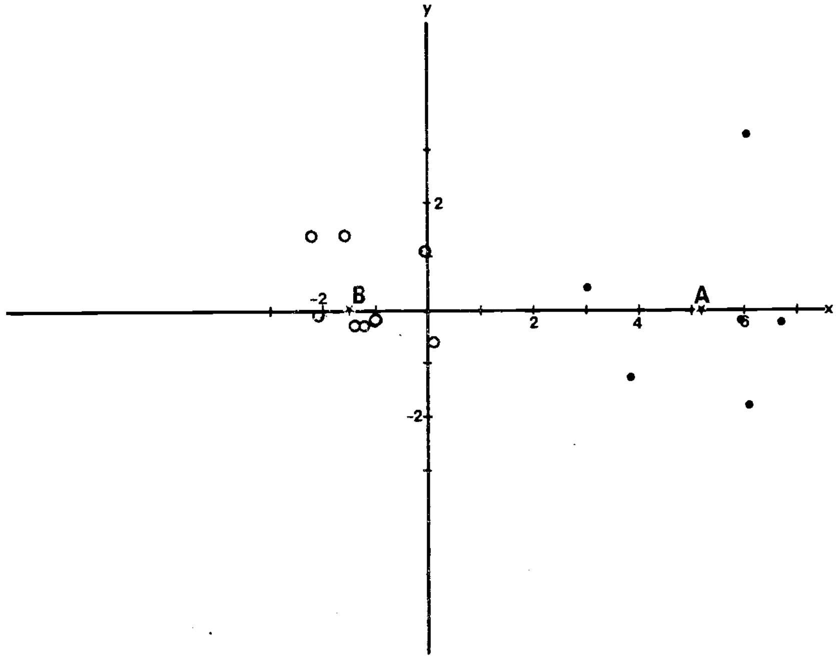
Group A and B represent Subassociations 1A and 1B of Association J (Cnidoscolus angustidens).

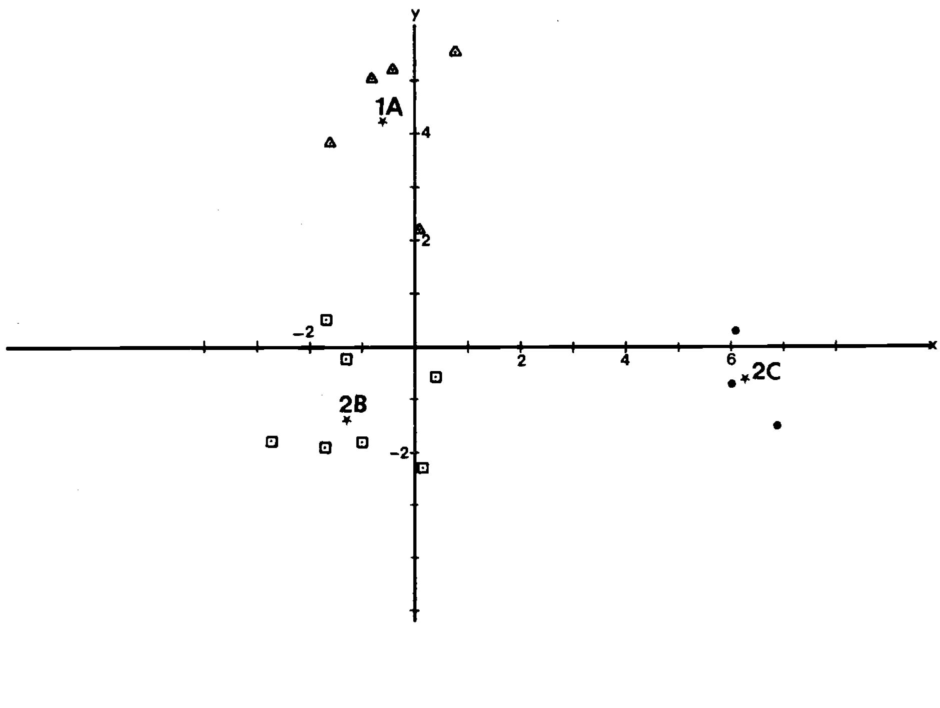
*Indicates the group means.

Figure 18. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Tombstone Hills (TH) data set.

Subgroups 1A; 2B and 2C correspond to Subassociations 1A and 1B of Association J (Cnidoscolus angustidens).

*Indicates the subgroup means.


y
2
-2
B
A
2
4
6
x
-2


y
1A
4
2
-2
2
4
6
x
2C
2B
-2

The graph of the first two canonical variables is shown in Figure 18. The subgroups are well defined although one may expect subgroups 2B and 2C to be more closely related to each other since they come from the same group. The graph shows the contrary, however. The total dispersion at this level is explained by the first two canonical variables, the first and the second accounting for 56 and 100 percent, respectively.

The Limestone Hills (LH) Data Set

The results of the SDA on two groups at the first hierarchical level representing Subassociations 1A and 1B of Association M (Mortonia scabrella) had 12 stands each. Three species were required to obtain a perfect discrimination between groups. These species were as follows: Leptochloa dubia (Ledu), Acacia constricta (Acco), and Opuntia pheacantha (Opph).

The pairwise differences between group means were significant at .01 probability by the inclusion of the first species, Leptochloa dubia. The results of plotting the first against the second canonical variable (Figure 19) indicates that the groups are well separated. Note, however, that the (x) and (y) coordinate means for both groups have the same absolute value: $x = |4.27|$, $y = 0$. The reasons were that the number of cases per group is the same, and only the first canonical variable is important since it accounts for the total dispersion.

At the second hierarchical level, the two groups corresponding to Subassociations 1A and 1B of Association M (Mortonia scabrella) were subdivided into four subgroups having 9, 3, 7, and 5 stands each. Eight out of 12 attributes used in the SDA were required to obtain perfect discrimination. The best two discriminants at this level were the same as level one, Leptochloa dubia (Ledu) and Acacia constricta (Acco). There was significance at .01 probability among the six paired combinations of subgroup means at the fourth step when Eysenhardtia polystachya (Eypo) entered the process (Table 27). No change in the significance took place after the rest of the variables had been entered.

Table 27. Value of the F-matrix used to test the pairwise differences among the subgroup means on the second hierarchical level of the Limestone Hills (LH) data set.

Step	Species entered	Sub-group	1A	1B	2C	d.f.
1	Ledu	1B	.62			1 20
		2C	70.00**	47.25**		
		2D	57.14**	42.18**		
2	Acco	1B	.86			2 19
		2C	96.72**	48.36**		
		2D	94.82**	51.35**	.95	
3	Teco	1B	1.27			3 18
		2C	63.08**	33.98**		
		2D	62.65**	32.67**	8.44**	
4	Eypo	1B	10.76**			4 17
		2C	45.38**	37.36**		
		2D	44.65**	29.24**	7.46**	

**Significance of F values for separation of subgroups at .01 probability level.

Figure 19. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Limestone Hills (LH) data set.

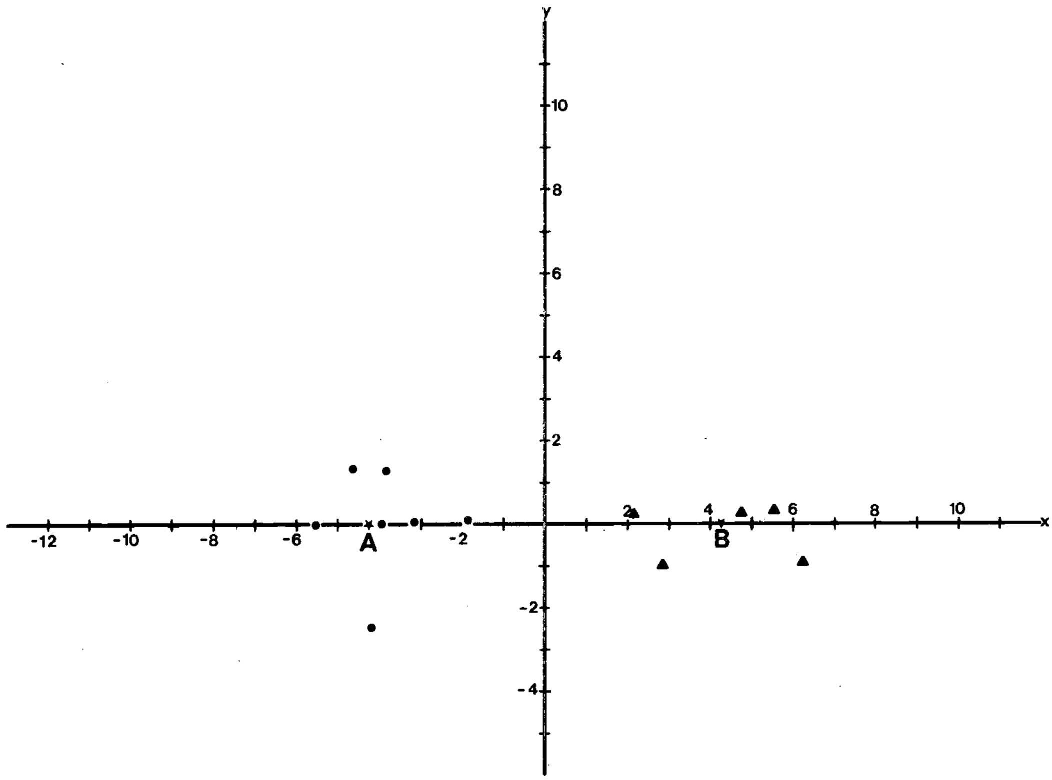
Groups A and B represent Subassociations 1A and 1B of Association M (Mortonia scabrella).

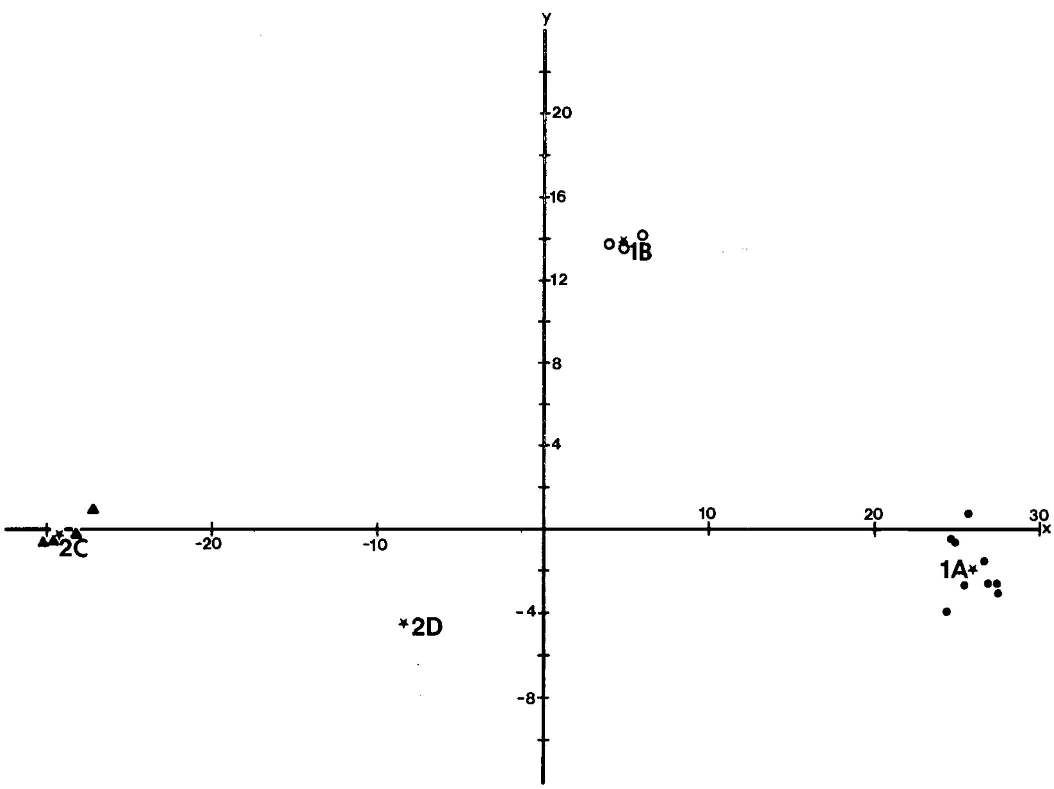
*Indicates the group means.

Figure 20. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Limestone Hills (LH) data set.

Subgroups 1A, 1B; 2C, and 2D belong to Subassociations A and B of Association M (Mortonia scabrella).

*Indicates the subgroup means.


y
10
8
6
4
2
-2
-4
-12
-10
-8
-6
-2
2
4
6
8
10
x
A
B


y
20
16
12
8
4
-4
-8
-20
-10
10
20
30
x
1B
2C
1A
2D

The subgroups obtained after plotting the first two canonical variables are presented in Figure 20. The subgroup separation is clear; subgroup 2D is the most homogeneous since the coordinates of the first and second canonical variable are the same. This result indicates that the variables from which the two canonical values originated have the same values. This statement was verified after looking at the original data since 11 attributes were absent from this group and the other has 100 percent presence as well as uniform cover values. At this particular level, the first three canonical variables accounted for the total dispersion. The first and second ones accounted for .93 and .99 percent. In a situation like this, one may desire to have a three dimensional picture of the subgroups since there were just three canonical variables involved; however, the subgroup separation is such that this is not necessary.

Proportionate Random Sample (PRS) Data Set

The last data set that was subjected to the SDA is a composite obtained by drawing a proportionate random sample from each of the nine original groups (CD, . . ., LH). At the first level, three groups having 14, 13, and 10 stands each were used. They can be identified as Alliance I, II, and III, respectively (Table 5). The 12 species used in the SDA were required to achieve perfect discrimination among the groups. The first and second best discrimants were Agave palmeri

(Agpa 1) and Acacia constricta (Acco). The significance of pairwise differences among group means at a .01 probability level was obtained at step three when Flourensia cernua (Flce) entered (Table 28).

Table 28. Values of the F-matrix used to test the pairwise differences among the group means on the first hierarchical level of the proportionate random sample (PRS) data set.

Step	Species entered	Group	A	B	d.f.
1	Agpa 1	B	.07		1 34
		C	30.23**	32.09**	
2	Acco	B	.10		2 33
		C	46.36**	48.98**	
3	Flce	B	7.32**		3 32
		C	36.03**	31.66**	

**Significance of F values for separation of group means at .01 probability level.

After this last step the level of significance remained unchanged. The groups obtained after plotting the first two canonical variables are given in Figure 21.

Group A is well separated from B and C (Figure 21). The latter appears to be the one with the largest within group dispersion. The first and second canonical variables accounted for the total dispersion.

At the second level, seven subgroups of 7, 7, 5, 4, 4, 5, and 5 stands each were considered, partially corresponding to the associations as described in section on p. 89-95. Twenty-one out of 24 attributes were required to achieve a perfect discrimination. Panicum hallii (Paha) and Dasylirion wheeleri (Dawh) became the first and second best discriminants. There was significance at .01 of the pairwise differences among the subgroup means except 1A and 1B (which is significant at .05) at the eighth step when Zinnia pumila (Zipu) entered the process. The .01 probability level among all the subgroups was reached by the inclusion of Eriogonum abertianum (Erab) at the twenty-fourth step even after the perfect discrimination was attained (Table 29).

The subgroups obtained after plotting the first two canonical variables are presented in Figure 22. Subgroups are well separated in general terms but as in the second level of the AH group already discussed, there are two subgroups (1A and 1B) that are closely related, at least this is the first impression that one receives after looking at those subgroups in Figure 22. Note the presence of the subgroup means only, the coordinates (x) and (y) of the first and second canonical variables have large values but are closely related to each other thus they become difficult to separate on a graph like this.

Evaluation of the Stepwise Discriminant Analysis

A summary of the stepwise discriminant analysis carried out at

Table 29. Values of the F-matrix used to test the differences among the subgroup means on the second hierarchical level of the Proportionate Random Sample (PRS) data set.

Step	Species entered	Subgroup	1A	1B	2C	2D	2E	3F	d.f.
1	Paha	1B	2.50						1 30
		2C	102.08**	75.00**					
		2D	89.09**	65.45**	0				
		2E	0	1.81	77.77**	70.00**			
		3F	0	2.08	87.50**	77.77**	0		
		3G	0	2.08	87.50**	77.77**	0	0	
2	Agpa 1	1B	1.47						2 29
		2C	49.56**	36.25**					
		2D	43.25**	31.63**	0				
		2E	0	1.07	37.76**	33.98**			
		3F	54.62**	48.85**	83.03**	74.04**	41.62**		
		3G	2.90	2.52	43.59**	38.74**	2.21	27.70**	
3	Deco	1B	1.02						3 28
		2C	33.44**	24.31**					
		2D	27.89**	20.36**	.74				
		2E	21.38**	19.95**	34.78**	37.01**			
		3F	59.42**	53.28**	65.24**	64.30**	26.79**		
		3G	2.69	2.05	28.15**	25.26**	13.87**	31.66**	
4	Muar 1	1B	.76						4 27
		2C	25.45**	19.16**					
		2D	20.30**	14.95**	.95				
		2E	46.22**	43.83**	63.13**	54.14**			
		3F	78.36**	72.36**	90.06**	77.04**	19.37**		
		3G	3.14*	2.40	24.57**	19.93**	27.90**	43.11**	

(Continued on next page)

Table 29 (Continued).

Step	Species entered	Subgroup	1A	1B	2C	2D	2E	3F	d. f.
5	Evar	1B	.62						5 26
		2C	21.94**	16.58**					
		2D	15.94**	11.67**	1.40				
		2E	68.75**	68.86**	93.71**	72.99**			
		3F	69.98**	64.29**	71.49**	64.14**	80.31**		
		3G	2.44	1.85	20.56**	15.50**	51.82**	40.69**	
6	Spgr	1B	.50						6 25
		2C	23.38**	18.96**					
		2D	12.79**	9.36**	4.99**				
		2E	60.18**	60.16**	75.08**	61.99**			
		3F	56.34**	51.81**	64.65**	51.74**	70.92**		
		3G	1.96	1.49	21.71**	12.46**	46.20**	38.78**	
7	Acco	1B	.43						7 24
		2C	19.31**	15.62**					
		2D	10.56**	7.71**	4.11**				
		2E	50.54**	50.80**	63.17**	52.14**			
		3F	46.65**	42.79**	53.25**	42.66**	60.35**		
		3G	4.72**	3.87**	19.78**	12.10**	44.19**	28.27**	
8[1]	Zipu	1B	2.64*						8 23
		2C	16.82**	13.44**					
		2D	9.51**	6.69**	3.45**				
		2E	42.49**	45.21**	53.97**	44.74**			
		3F	36.60**	36.34**	44.66**	35.79**	51.45**		
		3G	4.01**	5.83**	17.48**	11.06**	37.07**	24.45**	

(Continued on next page)

Table 29. (Continued)

Step	Species entered	Subgroup	1A	1B	2C	2D	2E	3F
⋮								
24	Erab[2]	1B	10.75**					
		2C	37805.33**	38768.07**				
		2D	248.40**	377.74**	24375.35**			
		2E	246345.80**	248740.40**	87039.34**	2013.74**		
		3F	64.39**	6211.37**	61619.72**	6492.11**	274776.66**	
		3G	4162.57**	4490.99**	14644.01**	1882.17**	166704.38**	16949.70**

[1]High significance among the groups was found up to the last step (24th), even after the perfect discrimination was achieved at the 21st step.

[2]It took 24 variables (species) to obtain significance at .01 level among the subgroups.

*, **Significance of F values for separation of subgroups at .05 and .01 probability levels.

Figure 21. Group separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the first hierarchical level of the Proportionate Random Sample (PRS) data set.

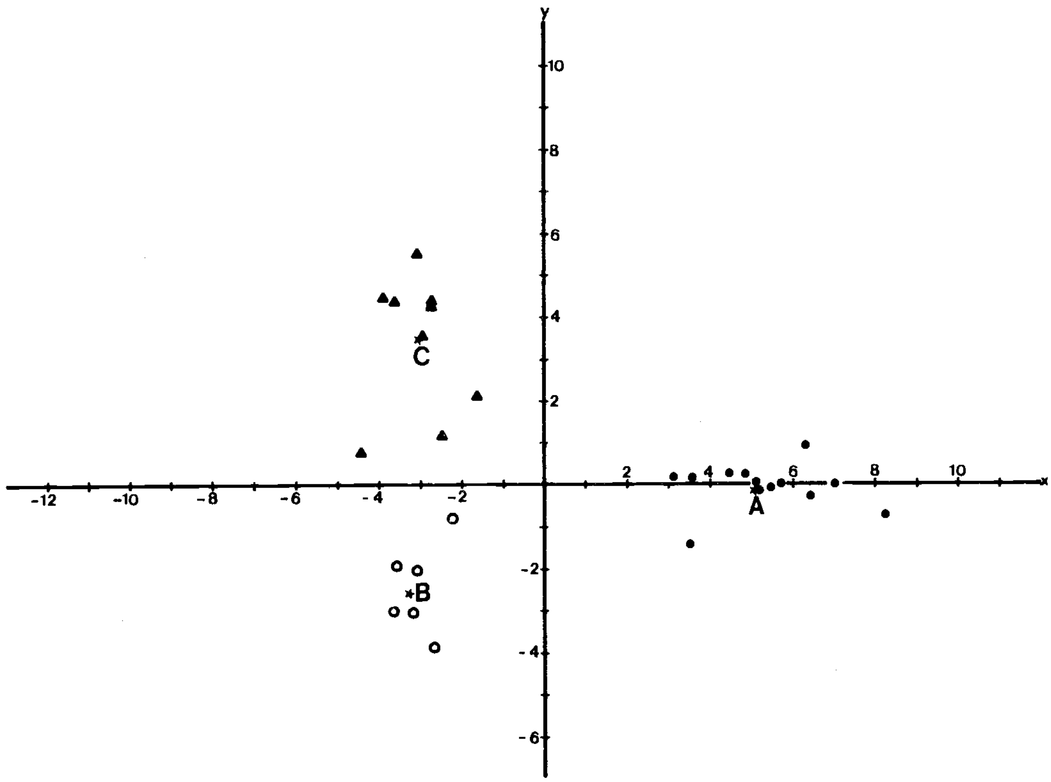
Groups A, B, and C correspond to Alliance I (*Acacia vernicosa*-*Larrea tridentata*-*Flourensia cernua*), Alliance II (*Yucca elata*/*Bouteloua eriopoda*), and Alliance III (*Fouquieria splendens*-*Acacia constricta*-*Aloysia wrightii*).

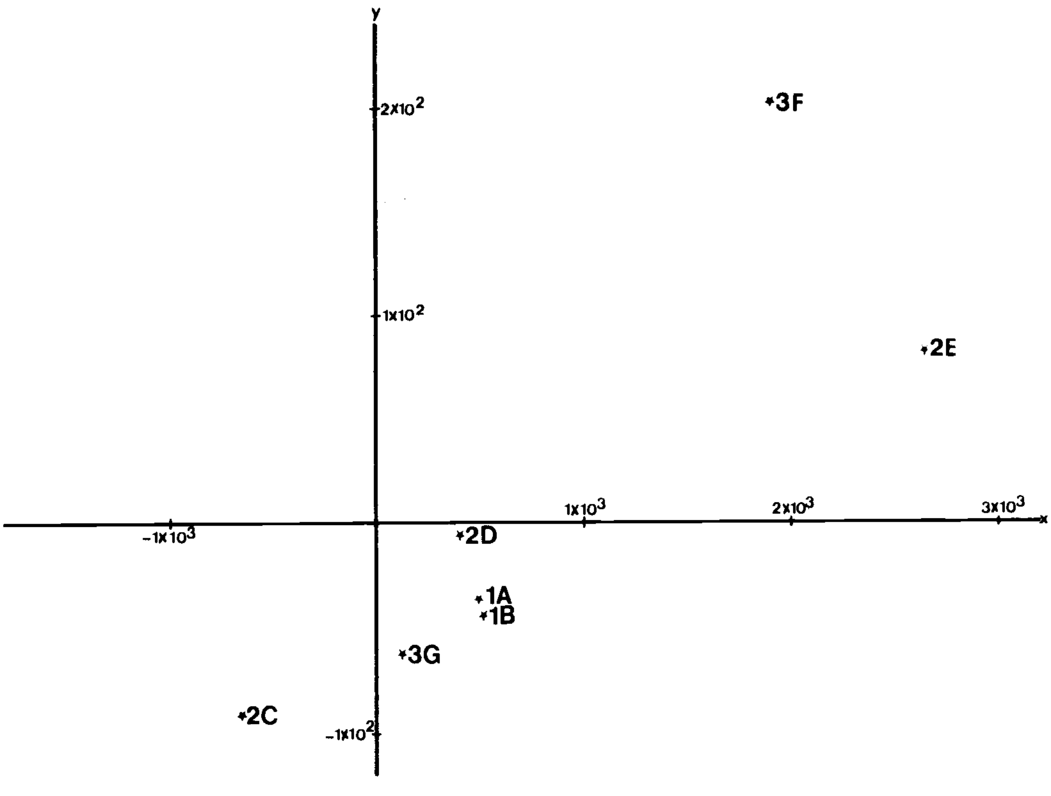
*Indicates the group means.

Figure 22. Subgroup separation obtained from plotting the first canonical variable (x) against the second canonical variable (y) at the second hierarchical level of the Proportionate Random Sample (PRS) data set.

Subgroups 1A, 1B, 2C, 2D, 2E, 3F, and 3G correspond partially to Associations A, B, C, D, E, I, and J, respectively (see Table 13).

*Indicates subgroup means.


y
10
8
6
4
2
-2
-4
-6
x
-12
-10
-8
-6
-4
-2
2
4
6
8
10
C
B
A


y
2x10²
1x10²
-1x10²
x
-1x10³
1x10³
2x10³
3x10³
3F
2E
2D
1A
1B
3G
2C

first (group) and second (subgroup) hierarchical levels in each of the ten data sets already discussed is presented in Table 2 (Appendix). It is quite evident from the results that:

1. Given the richness of the flora of the study area in all the data sets (except one--DR) the number of species having some differential value exceeded by far the capabilities of the computer program. However, in all cases pattern displayed by the species on the classification outputs played an important role in the selection of those species to be used to carry out the SDA. This limitation should be kept in mind.

2. The increase in the number of species identified as discriminants in the process (at both levels) is more a function of the data involved rather than the number of groups and subgroups into which each set is divided as well as the number of stands per group or subgroup.

3. It was observed that the best discriminants appear at both levels entering in the same order or changing it somewhat. This reflects the not infrequent differential power of a species at more than one level in a classification hierarchy.

4. The best discriminants are found to be good differential or character species. This confirms the validity of units classified following phytosociological concepts and also shows

the compatibility of qualitative (presence and absence) data used in the group and subgroup identification with the quantitative cover value estimates used in the SDA. Ubiquitous species were identified in some cases as discriminants, but their discriminating power was low.

5. At some point the number of groups (and particularly subgroups) selected becomes so large that the selected species cannot discriminate between or among them.

6. Perfect discrimination between and among groups and subgroups was achieved in all except at the second level of the DR Data Set where nine subgroups were considered. This does not mean some probability of misclassification exists for any given stand at any particular level, but the program has been worked out so that each case is classified into the group or subgroup where the largest probability to fit exists.

7. The significance at .01 probability of the pairwise group and subgroup means comparison was reached in almost all the sets before the perfect discrimination was achieved. An exception was found at the second level of the Proportionate Random Sample (PRS) Data Set. From here it can be said that group and subgroup separation could be obtained by using those species required to get significance at .01

probability although it would not be as clear as when all the variables required for perfect discrimination are used.

8. Generally speaking, with the increase in groups and subgroups, more of the total dispersion is distributed among canonical variables other than just the first and the second that are plotted in the graph. This creates some problems in the interpretation of group and subgroup separation as seen in a two dimensional display. Sometimes much dispersion is left unaccounted for because other canonical variables could not have been fitted into the two dimensional diagram.

SUMMARY AND CONCLUSIONS

The results of a preliminary vegetation classification on a semi-arid area of approximately 164, 144 acres in the Tombstone, Arizona, vicinity are presented. A total of 440 species were identified and 417 stands were observed. Information concerning vegetation, soil surface characteristics and physiography were documented in each stand. The data were divided into nine data sets. An additional set was derived by drawing a proportionate random sample from each of the nine individual sets. This breakdown of the data was done to comply with operational limitations of the computer facility and to enable comparison of classification results from a composite data set with results from the separate analyses.

A computer "program package" has been designed as a substitute for the cumbersome task of hand sorting data. It introduces, thus, more objectivity, efficiency and manipulation capacity into the process. Presence and absence vegetation data and standardized cover value estimates were used in the present study.

The fundamental unit of vegetation classification, association, has been determined by the use of character species. The association is the basis for defining the upper and lower rank units, alliances and subassociations, respectively.

The vegetation of the study area has been tentatively classified into hierarchical units according to the Zurich-Montpellier school of phytosociology. These units are as follows:

Alliance I (*Acacia vernicosa*-*Larrea tridentata*-*Flourensia cernua*)

Alliance II (*Yucca elata*/*Bouteloua eriopoda*)

Alliance III (*Fouquieria splendens*-*Acacia constricta*-*Aloysia wrightii*)

Alliance I includes the following associations and a variant:

A (*Panicum hirticaule*/*Tidestromia lanuginosa*-*Boerhaavia coulteri*)

1a - A variant and

B (*Rhus microphylla*-*Dalea formosa*)

Alliance II includes the following associations:

C (*Gutierrezia sarothrae*/*Eriogonum abertianum*)

D (*Menodora scabra*/*Tridens grandiflorus*)

E (*Hilaria belangeri*) and

F (*Gilia rigidula*-*Rhynchosia texana*)

Alliance III includes the following associations:

I (*Ayenia pusilla*/*Eragrostis intermedia*)

J (*Cnidoscolus angustidens*) and

K (Typical association)

Additional associations were also characterized. These include:

G (*Hilaria mutica*/*Eriochloa gracilis*/*Crotalaria pumila*)

H (*Haplopappus tenuisectus*/*Eragrostis lehmanniana*)

L (*Agave palmeri*-*Agave parryi*/*Haplopappus laricifolius*) and

M (*Mortonia scabrella*).

Each of the above associations has two or more well defined sub-associations.

The results obtained by the use of these analytical programs in the present study clearly grouped the vegetation into classifiable units and showed the patterns and hierarchical relationships of the vegetation of the study area. It was observed that the detection of pattern in lower rank units (association and subassociation) was more readily accomplished when a sample size was less than 50 stands per group.

From the pattern observed in each group, it is rather easy to identify species (character and differential) which are useful in the classification process and in field recognition. My results indicate that presence and absence data generally provide a better classification for all the data sets except for the LH and TH data sets which originated Association M (Mortonia scabrella) and Association J (Cnidoscolus angustidens). Here standardized cover values provided a more satisfactory classification. In these cases the phytosociological groups were more readily identified from the computer output and on the dendrograms of the quantitative data. In Association M there was a differentiating pattern in the cover values at subassociation level when differences in absolute cover value were considered as well as consistency of occurrence of the differentiating taxon in the subgroups. In numerous cases a subgroup was well differentiated by significantly high cover values even though they lacked symmetry in the dendrogram.

In the latter, Association J, the groups were more sharply differentiated on these same criteria and they were, in addition, more symmetric in the dendrogram with respect to the number of stands found per group. There was no question about the classification of the other eight groups (CD, BR, DR, PRS, KR, GR, MU, and AH) using presence and absence data alone. In the MU and AH groups, standardized cover values failed to show the existing pattern.

In the KR and GR sets there was some difficulty in selecting the classification scheme from presence and absence data versus standardized values, particularly when the pattern of the second hierarchical level (subassociation) was evaluated. For these two groups the pattern from standardized data at the subassociation was better than from presence and absence data. A possible explanation for this is the shifting of one or more stands from one subgroup to another within the same group when presence/absence and standardized data are compared. This change may not affect the overall classification of the entire group at the first hierarchical level (association). However, at the subassociation level, where one is dealing with a reduced number of stands, the shift of a well structured stand from one subgroup to the other may cause the consolidation of a subgroup(s). The inclusion of that well structured stand may form the core of a new subgroup just by the nature and kind of information contained in it.

Furthermore, when the dendrograms and the printouts derived from each phytosociological taxa coming from presence and absence data are compared with those coming from the standardized cover estimates, the separation and symmetry (number of stands per group) of the groups were better in the former data than in the latter. Moreover, chaining[16] was also slightly less with presence and absence data.

Misclassifications of stands were detected from observation of the classification outputs and in the dendrograms. In the classification outputs, the species included in those stands were too numerous or too few and did not show any relationship to the meaningful species groups from the other stands; in the dendrograms, the misclassified stands showed as isolated branches having no relationship with the rest of the group or groups. This was shown by an increase in the value of the distance where they join in the dendrogram at the very bottom. However, these isolated cases of questionable classification were left in the sets as a matter of record for mapping purposes, experiments, and for field recognition tests later on. Mapping requires that a classification decision be made about each stand. The classification placed these problem stands with the best fit group.

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[16]Chaining is the tendency of a given group to grow in size by the addition of single individuals or groups much smaller than itself, rather than by fusion with another group of comparable size (Lambert and Williams, 1966).

Units that showed some similarities among themselves were pooled into higher rank units and a tentative descriptor was assigned to each. The validity of initial breakdown of the data into nine groups to facilitate the analysis was tested by a proportionate random sample from all the groups involved. The pattern of the proposed higher rank units was fully reproduced and associations were partially reproduced. Stand numbers were not sufficient in the PRS to allow a subassociation classification.

The discriminatory value of the character and differential species in characterizing or identifying the associations and subassociations was tested by the use of stepwise discriminant analysis. It was found that the best discriminants were the differential or character species resulting from the classification irrespective of their growth form. This confirms the validity of these units, as well as the importance of a complete species list in doing classification studies.

Reports in the literature question the importance of annuals in vegetation studies since their occurrence and distribution is related to variations in climate, disturbance, etc. (Grunow, 1967; Daubenmire, 1968). My results and Segura's (1970) indicate the importance of having them in the analysis since they are found frequently to be good identifiers between and among phytosociological taxa and good discriminants in the stepwise discriminant analysis. In addition, my results indicate annuals do have phytosociological value since they have some degree of fidelity for certain plant communities. By so doing, they identify themselves with certain phytosociological taxa. Moreover, when these annual species are combined or grouped as indicators with perennials occurring on the identical sites, the identification of these taxa in the field is greatly facilitated. Inclusion of annuals as discriminants also enhances one's chances of correctly identifying phytosociological taxa in spite of varying impacts of man and animal use on the vegetation resource.

The number of attributes (species) required to achieve a perfect discrimination depends very much upon the number of the units considered and the similarity or distinctiveness of the groups.

A perfect discrimination was found in all the groups and subgroups tested except one (subgroup 2F of the GR Data Set). This does not necessarily mean that there is probability of stand misclassification from one group to the next; but as the program was designed, the stand would be classified into the group for which the probability is highest that it does belong.

The test of significance at .01 probability between and among the pairwise comparison of group means, and thus of the discrimination, was always achieved by the inclusion of fewer species than those required to achieve a perfect discrimination. This indicates that the process could be stopped after this particular step (the $P = .01$ level) with the risk of not having quite as good a separation as when the program was allowed to run until the species necessary to achieve a perfect discrimination were used. The graph resulting from plotting the first (x) against the second canonical variable (y)--a function of the species used in the stepwise discriminant function (SDA)--is somewhat incomplete in cases where the number of groups is greater than three. The reason is that some dispersion is left unaccounted for. This caused some difficulty in displaying the SDA results for separating groups in two dimensions when in fact they were in multi-dimensional space.

It is expected that the proposed phytosociological units as determined by the use of the character and differential species for the study area are satisfactory; how well they would hold on surrounding areas or regions having similar vegetation remains to be seen. Küchler (1967) points out that character and differential species are good identifiers for associations and subassociations while dealing with a small region. He further comments (p. 253) that as the region expands, "the hierarchy becomes more and more blurred and many well defined units will go into transitions." This statement can be interpreted as being partially valid since in some cases this would happen--but in most instances the association(s) repeat themselves or are replaced by other associations as one moves from one area to another within the same region or regions.

My classification scheme was devised with one main objective--the detection of the relationships among the objects included. It is a working hypothesis to be tested by further work and the confirmation of its validity would come, according to Moore (1962, p. 764), by the following steps:

1. From further floristic data critically and impartially collected with a view of testing the hypothesis.
2. From mapping the units distinguished. Two careful workers should arrive independently at the same boundaries if the association tables from which they are working are valid.
3. Coincidence between the vegetational units distinguished and certain environmental factors.

This last point is quite important and can avoid misinterpretations when other environmental factors such as soil texture and its relation to water holding capacity (Anderson, 1956; Donselaar, 1965), vegetation and soil (Poulton and Tisdale, 1961) are brought into the picture to complement the vegetation classification so that some cause-effect relationships can be postulated or understood. It should be remembered, however, that what we were after in this study ia s vegetation unit rather than an ecological unit.

While this may be considered a provisional classification or a first approximation, it will provide other people with a reference point or it may challenge others to develop a better classification system. As long as users recognize that more study or use of this classification scheme in the region may reveal exceptions or omissions, the advantages of its use should outweigh the disadvantages until such time as additional research on a broader regional scale can strengthen and improve upon what I have done.

RECOMMENDATIONS

It should be remembered that the validity of the classification presented in this study is a function of the original stand definition, the kind of data recorded, the number and size of groups considered, and the operational limitations of the classification procedures.

The phytosociological taxa presented herein are not suggested as absolute, they are working hypotheses which have to be tested and either accepted, improved, or rejected once there is more information available on their practical usability. The most effective way to test the validity of a vegetation classification is by field checking to determine how well the classification units portray the features found on the ground. In addition, such units may have unique signatures thus providing the means for accurately identifying photo images.

More research is needed to determine the optimum means of dividing large amounts of data--either by growth form, physiognomy, physiographic features, geography, or a combination thereof--to get within the capacity limitations of the programs.

Research needs to be done to explain why Euclidean distance (as a measure of similarity) and Ward's method (the sorting strategy) provide a better classification scheme using presence and absence data than standardized cover value estimates.

Undoubtedly, better results could have been obtained in this research study if I had more intensively sampled those areas having complex physiographic and vegetational features such as the Andesite and Tombstone Hills, and the Mule Mountains.

It is suggested that a multidisciplinary approach to study the natural resources of an area is by far the soundest way to do an effective job in determining its potentialities and limitations. A team of resource-oriented scientists composed of a soil scientist (soil genesis and classification), an ecologist (community), and a botanist (taxonomist) should provide as much basic information as is needed. Economic as well as socio-political considerations should be introduced into the management decision-making process since they are as important as the natural science disciplines. In following this approach, different kinds of information would be assembled simultaneously, thus saving time and energy. The extra expense involved in using the team approach would be compensated for by the higher quality of information gathered, the more efficient use of time and skill, and by the minimization of duplicatory efforts.

The human-machine interaction is important while dealing with numerical taxonomic methods. No matter how impressive the results obtained by the use of computers may be, the scientist should have the ability and accuracy of judgment to spot any errors in the computer output and correct them immediately. It should be kept in mind that the computer is merely a tool that helps relieve the scientist of manual calculations but the ultimate decision for accuracy of the classification always rests with the scientist. He is the one who must judge the biological accuracy of the results from machine analysis.

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APPENDICES

Appendix Table 1. Species found on the study area arranged alphabetically by growth form.

Alphanumeric symbol	Scientific name	Growth form
CERE	*Celtis reticulata* Torr.	01
CHLI	*Chilopsis linearis* (Cav.) Sweet	01
JUMA	*Juglans major* (Torr.) Heller	01
JUDE	*Juniperus deppeana* Steud.	01
PLWR	*Platanus wrightii* Wats.	01
POFR	*Populus fremontii* Wats.	01
PRJU	*Prosopis juliflora* (Swartz) DC.	01
QUAR	*Quercus arizonica* Sarg.	01
QUEM	*Quercus emoryi* Torr.	01
QUOB	*Quercus oblongifolia* Torr.	01
QURU	*Quercus rugosa* Nee	01
SASA	*Sapindus saponaria* L.	01
ACAN	*Acacia angustissima* (Mill.) Kuntze	02
ACCO	*Acacia constricta* Benth.	02
ACGR	*Acacia greggii* Gray	02
ACVE	*Acacia vernicosa* Standl.	02
ALWR	*Aloysia wrightii* (Gray) Heller	02
ANTH	*Anisacanthus thurberi* (Torr.) Gray	02
ARPU	*Arctostaphylos pungens* H. B. K.	02
ATCA	*Atriplex canescens* (Pursh) Nutt.	02
AYMI	*Ayenia microphylla* Gray	02
BAPT	*Baccharis pteronioides* DC.	02
BASA	*Baccharis sarothroides* Gray	02
BATH	*Baccharis thesioides* H. B. K.	02
BEIN	*Bernardia incana* Morton	02
BOGL	*Bouvardia glaberrima* Engelm.	02
BRICK	*Brickellia* sp.	02
BRCA	*Brickellia californica* (Torr. & Gray) Gray	02
CAGI	*Caesalpinia gilliesii* Wall.	02
CAER	*Calliandra eriophylla* Benth.	02
CEGR	*Ceanothus greggii* Gray	02
CEBR	*Cercocarpus breviflorus* Gray	02
CHAR	*Choisya arizonica* Standl.	02
CHNAG	*Chrysothamnus nauseosus gnaphalodes* (Greene) H. M. Hall	02
COCA	*Coldenia canescens* DC.	02
COLYC	*Condalia lycioides canescens* (Gray) Trel.	02
COSP	*Condalia spathulata* Gray	02
COME	*Cowania mexicana* D. Don	02
DAFO	*Dalea formosa* Torr.	02
DAWI	*Dalea wislizenii* Gray	02
DECO	*Desmanthus cooleyi* (Eaton) Trel.	02
ENFA	*Encelia farinosa* Gray	02
EPHED	*Ephedra* sp.	02
EPTR	*Ephedra trifurca* Torr.	02
ERWR	*Eriogonum wrightii* Torr.	02
ERFL	*Erythrina flabelliformis* Kearney	02

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
EULA	Eurotia lanata (Pursh) Moq.	02
EYPO	Eysenhardtia polystachya (Ortega) Sarg.	02
FECY	Fendlerella cymosa (Greene) Kearney & Peebles	02
FLCE	Flourensia cernua DC.	02
FOSP	Fouquieria splendens Engelm.	02
GOTH	Gossypium thurberi Todaro	02
GUSA	Gutierrezia sarothrae (Pursh) Britt. & Rusby.	02
HALA	Haplopappus laricifolius Gray	02
HATE	Haplopappus tenuisectus (Greene) Blake	02
HICO	Hibiscus coulteri Harv.	02
HYMO	Hymenoclea monogyra Torr. & Gray	02
JUMO	Juniperus monosperma (Engelm.) Sarg.	02
KOSP	Koeberlinia spinosa Zucc.	02
KRPA	Krameria parvifolia Benth.	02
LATR	Larrea tridentata (DC.) Coville	02
LYCIU	Lycium sp.	02
LYAN	Lycium andersonii Gray	02
LYBE	Lycium berlandieri Dunal.	02
LYPA	Lycium pallidum Miers	02
MESC	Menodora scabra Gray	02
MIBI	Mimosa biuncifera Benth.	02
MOSC	Mortonia scabrella Gray	02
PAIN	Parthenium incanum H.B.K.	02
PECA	Petrophytum caespitosum (Nutt.) Rydb.	02
PHMI	Philadelphus microphyllus Gray	02
PRSE	Prunus serotina Ehrh.	02
PRSEV	Prunus serotina virens (Woot. & Standl.) McVaugh	02
RHCH	Rhus choriophylla Woot. and Standl.	02
RHMI	Rhus microphylla Engelm.	02
RHTR	Rhus trilobata Nutt.	02
SAPA	Salvia parryi Gray	02
SAPI	Salvia pinguifolia (Fren.) Woot. & Standl.	02
SEGL	Selloa glutinosa Spreng.	02
SELO	Senecio longilobus Benth.	02
TEST	Tecoma stans (L.) H.B.K.	02
TESTA	Tecoma stans angustata Rehder	02
TRCA	Trixis californica Kellogg	02
CEGRT	Cereus greggii transmontanus Engelm.	03
COVI	Coryphantha vivipara (Nutt.) Britton & Rose	03
COVIA	Coryphantha vivipara arizonica (Engelm.) W. T. Marshall	03
COVIB	Coryphantha vivipara bisbeeana (Orcutt) L. Benson	03
ECENE	Echinocereus engelmannii engelmannii (Parry) Lemaire	03
ECFAF	Echinocereus fasciculatus fasciculatus (Engelm.) L. Benson	03
ECPER	Echinocereus pectinatus rigidisimus (Engelm.) Engelm. ex Rumpler	03
EPMI	Epithelantha micromeris (Engelm.) Weber	03
FEWI	Ferocactus wislizenii (Engelm.) Britton & Rose	03
MAMMI	Mammilaria sp.	03

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
MAMMI1	Mammilaria sp.	03
MAGUA	Mammilaria gummifera applanata (Engelm.) L. Benson	03
MAGUM	Mammilaria gummifera mac dougalii (Rose) L. Benson	03
MAMI	Mammilaria microcarpa Engelm.	03
NEER	Neolloydia erectocentra (Coulter) L. Benson	03
NEERE	Neolloydia erectocentra erectocentra (Coulter) L. Benson	03
NEIN	Neolloydia intertexta (Engelm.) L. Benson	03
OPCH	Opuntia chlorotica Engelm. & Bigelow	03
OPLE	Opuntia leptocaulis DC.	03
OPPH	Opuntia phaeacantha Engelm.	03
OPPHD	Opuntia phaeacantha discata (Griffiths) Benson & Walkington	03
OPSP	Opuntia spinosior (Engelm.) Toumey	03
OPVI	Opuntia violacea Engelm.	03
OPVIM	Opuntia violacea macrocentra (Engelm.) L. Benson	03
AGPA 1	Agave palmeri Engelm.	04
AGPA	Agave parryi Engelm.	04
AGPAH	Agave parryi huachucensis (Baker) Little	04
DAWH	Dasylirion wheeleri Wats.	04
NOMI	Nolina microcarpa Wats.	04
YUBA	Yucca baccata Torr.	04
YUEL	Yucca elata Engelm.	04
YUSC	Yucca schottii Engelm.	04
ANCI	Andropogon cirratus Hack.	05
ARIST	Aristida sp.	05
ARAR	Aristida arizonica Vasey	05
ARBA	Aristida barbata Fourn.	05
ARDI	Aristida divaricata Humb. & Bonpl.	05
ARGL	Aristida glabrata (Vasey) Hitchc.	05
ARGL 1	Aristida glauca (Nees) Walp.	05
ARHA	Aristida hamulosa Henr.	05
ARLO	Aristida longiseta Steud.	05
AROR	Aristida orcuttiana Vasey	05
ARPA	Aristida pansa Woot. & Standl.	05
ARPA 1	Aristida parishii Hitchc.	05
ARPU 1	Aristida purpurea Nutt.	05
ARTE	Aristida ternipes Cav.	05
ARWR	Aristida wrightii Nash	05
BOBA	Bothriochloa barbinodis (Lag.) Herter	05
BOCH	Bouteloua chondrosioides (H. B. K.) Benth.	05
BOCU	Bouteloua curtipendula (Michx.) Torr.	05
BOEL	Bouteloua eludens Griffiths	05
BOER	Bouteloua eriopoda Torr.	05
BOFI	Bouteloua filiformis (Fourn.) Griffiths	05
BOGR	Bouteloua gracilis (H. B. K.) Lag.	05
BOHI	Bouteloua hirsuta Lag.	05
BORA	Bouteloua radicosa (Fourn.) Griffiths	05
BORO	Bouteloua rothrockii Vasey	05

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
BUDA	Buchloe dactyloides (Nutt.) Engelm.	05
COPA	Cottea pappophoroides Kunth.	05
DICA	Digitaria californica (Benth.) Henrad	05
ELBA	Elyonurus barbiculmis Hack.	05
ENDE	Enneapogon desvauxii Beauv.	05
ERIN	Eragrostis intermedia Hitchc.	05
ERLE	Eragrostis lehmanniana Nees	05
ERPU	Erioneuron pulchellum (H. B. K.) Tateoka	05
HECO	Heteropogon contortus (L.) Beauv.	05
HIBE	Hilaria belangeri (Steud.) Nash	05
HIMU	Hilaria mutica (Buckl.) Benth.	05
LEDU	Leptochloa dubia (H. B. K.) Nees	05
LECO	Leptoloma cognatum (Schult.) Chase	05
LYPH	Lycurus phleoides H. B. K.	05
MUAR	Muhlenbergia arenacea (Buckl.) Hitchc.	05
MUAR 1	Muhlenbergia arenicola Buckl.	05
MUAR 2	Muhlenbergia arizonica Scribn.	05
MUEM	Muhlenbergia emersleyi Vasey	05
MUPA	Muhlenbergia pauciflora Buckl.	05
MUPO	Muhlenbergia porteri Scribn.	05
MURE	Muhlenbergia repens (Presl) Hitchc.	05
PAAN	Panicum antidotale Retz.	05
PABU	Panicum bulbosum H. B. K.	05
PAHA	Panicum hallii Vasey	05
PAOB	Panicum obtusum H. B. K.	05
PAMU	Pappophorum mucronulatum Nees	05
SCBR	Scleropogon brevifolius Phil.	05
SEMA	Setaria macrostachya H. B. K.	05
SOHA	Sorghum halepense (L.) Pers.	05
SPAI	Sporobolus airoides Torr.	05
SPCO	Sporobolus contractus Hitchc.	05
SPCR	Sporobolus cryptandrus (Torr.) Gray	05
SPWR	Sporobolus wrightii Munro	05
STEM	Stipa eminens Cav.	05
STLE	Stipa lettermanii Vasey	05
STNE	Stipa neomexicana (Thurb.) Scribn.	05
TRMO	Trachypogon montufari (H. B. K.) Nees	05
TRGR	Tridens grandiflorus (Vasey) Woot. & Standl.	05
TRMU	Tridens muticus (Torr.) Nash	05
ARAD	Aristida adscensionis L.	06
BOAR	Bouteloua aristidoides (H. B. K.) Griseb.	06
BOBA 1	Bouteloua barbata Lag.	06
CEPA 1	Cenchrus pauciflorus Benth.	06
CHVI	Chloris virgata Swartz	06
ERAR	Eragrostis arida Hitchc.	06
ERCI	Eragrostis cilianensis (All.) Link.	06
ERDI	Eragrostis diffusa Buckl.	06
ERLU	Eragrostis lutescens Scribn.	06
ERME	Eragrostis mexicana (Hornem.) Link.	06

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Appendix Table 1. (Continued).

Alphanumeric symbols	Scientific name	Growth form
ERPE	Eragrostis pectinacea (Michx.) Nees	06
ERGR	Eriochloa gracilis (Fourn.) Hitchc.	06
LEFI	Leptochloa filiformis (Lam.) Beauv.	06
MUMI	Muhlenbergia minutissima (Steud.) Swallen	06
PAAR	Panicum arizonicum Scribn. & Merr.	06
PACA	Panicum capillare L.	06
PAHI	Panicum hirticaule Presl.	06
SEGR	Setaria grisebachii Fourn.	06
TRBE	Tragus berteronianus Schult.	06
CARU	Carex rusbyi MacKenz.	07
CYES	Cyperus esculentus L.	07
CYRU	Cyperus rusbyi Britton	07
ABUTI	Abutilon sp.	08
ABIN	Abutilon incanum (Link.) Sweet	08
ABPA	Abutilon parvulum Gray	08
ALIN	Allionia incarnata L.	08
ALKU	Allium kunthii Don	08
AMBRO	Ambrosia sp.	08
AMCO	Ambrosia confertiflora DC.	08
AMPS	Ambrosia psilostachya DC.	08
AMPA	Amoreuxia palmatifida Moc. & Sesse	08
ANTO	Anthericum torreyi Baker	08
APUN	Apodanthera undulata Gray	08
ARPL	Argemone pleiacantha Greene	08
ARPLP	Argemone pleiacantha pleiacantha	08
ARLU	Artemisia ludoviciana Nutt.	08
ASCLE	Asclepias sp.	08
ASLI	Asclepias linaria Cav.	08
ASMA	Asclepias macrotis Torr.	08
ASNU	Asclepias nummularia Torr.	08
ASSU	Asclepias subverticillata (Gray) Vail	08
ASHI	Aspicarpa hirtella Rich.	08
ASHI 1	Aster hirtifolius Blake	08
ASTA	Aster tagetinus (Greene) Blake	08
ASTA 1	Aster tanacetifolius H.B.K.	08
AYPU	Ayenia pusilla L.	08
BAAB	Bahia absinthifolia Benth.	08
BAMU	Baileya multiradiata Harv. & Gray	08
BELY	Berlandiera lyrata Benth.	08
BOCO	Boerhaavia coccinea Mill.	08
BOGR 1	Boerhaavia gracillima Heimerl	08
BRDE	Brayulinea densa (Humb. & Bonpl.) Small	08
BRFL	Brickellia floribunda Gray	08
BRVE	Brickellia venosa (Woot. & Standl.) Robins.	08
CAHU	Calliandra humilis Benth.	08
CAAR	Carlowrightia arizonica Gray	08
CABA	Cassia bauhinioides Gray	08

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Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
CALE	Cassia leptocarpa Benth.	08
CHCO 1	Chamaesaracha coniodes (Moric.) Britton	08
CHCO	Chamaesaracha coronopus (Dunal) Gray	08
CIWH	Cirsium wheeleri (Gray) Petrak	08
CNAN	Cnidoscolus angustidens Torr.	08
COER	Commelina erecta L.	08
COSC	Commicarpus scandens (L.) Standl.	08
COIN	Convolvulus incanum Vahl	08
CRCO	Croton corymbulosus Engelm.	08
CUDI	Cucurbita digitata Gray	08
DALEA	Dalea sp.	08
DAAL	Dalea albiflora Gray	08
DACA	Dalea calycosa Gray	08
DAGR	Dalea grayi (Vail) L. O. Williams	08
DAJA	Dalea jamesii (Torr.) Torr. & Gray	08
DALA	Dalea lachnostachys Gray	08
DANA	Dalea nana Torr.	08
DANE	Dalea neomexicana (Gray) Cory	08
DAPO	Dalea pogonathera Gray	08
DAWR	Dalea wrightii Gray	08
DIAR	Dichondra argentea Willd.	08
DINE	Ditaxis neomexicana (Muell. Arg.) Heller	08
DYDE	Dyschoriste decumbens (Gray) Kuntze	08
DYAC	Dyssodia acerosa DC.	08
DYPE	Dyssodia pentachaeta (DC.) Robins.	08
ELIM	Elytraria imbricata (Vahl) Pers.	08
EUGR	Eupatorium greggii Gray	08
EUPHO	Euphorbia sp.	08
EUAL	Euphorbia albomarginata Torr. & Gray	08
EVAL	Evolvulus alsinoides L.	08
EVAR	Evolvulus arizonicus Gray	08
EVPI	Evolvulus pilosus Nutt.	08
EVSE	Evolvulus sericeus Swartz	08
FRCO	Franseria confertiflora (DC.) Rydb.	08
FRAR	Froelichia arizonica Thornber	08
FUNAS	Funastrum sp.	08
FUCR	Funastrum crispum (Benth.) Schlechter	08
GAWR 1	Galactia wrightii Gray	08
GACO	Gaura coccinea Nutt.	08
GIMA	Gilia macombii Torr.	08
GIRI	Gilia rigidula Benth.	08
GNLE	Gnaphalium leucocephalum Gray	08
GNWR	Gnaphalium wrightii Gray	08
GOCA	Gomphrena caespitosa Torr.	08
GOSO	Gomphrena sonorae Torr.	08
HASP	Haplopappus spinulosus (Pursh) DC.	08
HACR	Haplophyton croosksii L. Benson	08
HEDE	Hedeoma dentatum Torr.	08

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Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
HENA	Hedeoma nanum (Torr.) Briq.	08
HECI	Helianthus ciliaris DC.	08
HIDE	Hibiscus denudatus Benth.	08
HODE	Hoffmanseggia densiflora Benth.	08
HODR	Hoffmanseggia drepanocarpa Gray	08
HOUST	Houstonia sp.	08
HORU	Houstonia rubra Cav.	08
HYVE	Hybanthus verticillatus (Ortega) Baill.	08
IPHE	Ipomoea heterophylla Ortega	08
JAGR	Janusia gracilis Gray	08
JAMA	Jatropha macrorhiza Benth.	08
KRLA	Krameria lanceolata Torr.	08
LEFE	Lesquerella fendleri (Gray) Wats.	08
LOOR	Lotus oroboides (H. B. K.) Ottley	08
MABR	Macrosiphonia brachysiphon (Torr.) Gray	08
MAAN	Manihot angustiloba (Torr.) Muell. Arg.	08
MELE	Melampodium leucanthum Torr. & Gray	08
MIBI 1	Milla biflora Cav.	08
NITR	Nicotiana trigonophylla Dunal	08
NIWI	Nissolia wislizenii Gray	08
OENOT	Oenothera sp.	08
OXLI	Oxybaphus linearis (Pursh) Robins.	08
OXLA	Oxytropis lambertii Pursh	08
PELO	Pectis longipes Gray	08
PEDA	Penstemon dasyphyllus Gray	08
PELI	Penstemon linarioides Gray	08
PEST	Penstemon stenophyllus Gray	08
PENA	Perezia nana Gray	08
PEWR	Perezia wrightii Gray	08
PESC	Peteria scoparia Gray	08
PHHE	Phaseolus heterophyllus Willd.	08
PHME	Phaseolus metcalfei Woot. & Standl.	08
PHCU	Phyla cuneifolia (Torr.) Greene	08
POAL	Polygala alba Nutt.	08
POLO	Polygala longa Blake	08
POMA	Polygala macradenia Gray	08
PORA	Polygala racemosa Blake	08
PORE	Polygala reducta Blake	08
POSC	Polygala scoparioides Chodat.	08
POTW	Polygala tweedyi Britton	08
POLYG	Polygonum sp.	08
POGR	Porophyllum gracile Benth.	08
PSTE	Psoralea tenuiflora Pursh.	08
RHTE	Rhynchosia texana Torr. & Gray	08
SINE	Sida neomexicana Gray	08
SIPR	Sida procumbens SW.	08
SILI	Sisymbrium linearifolium (Gray) Payson	08

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
SOEL	Solanum elaeagnifolium Cav.	08
SOJA	Solanum jamesii Torr.	08
SPAN	Sphaeralcea angustifolia (Cav.) G. Don	08
SPEM	Sphaeralcea emoryi Torr.	08
SPGR	Sphaeralcea grossulariaefolia (Hook. & Arn.) Rydb.	08
STTE	Stephanomeria tenuifolia (Torr.) H. M. Hall	08
TAAN	Talinum angustissimum (Gray) Woot. & Standl.	08
TAAU	Talinum aurantiacum Engelm.	08
TAPA	Talinum paniculatum (Jacq.) Gaertn.	08
TECO	Tetraclea coulteri Gray	08
THTE	Thamnosma texana (Gray) Torr.	08
THLO	Thelesperma longipes Gray	08
THME	Thelesperma megapotamicum (Spreng.) Kuntze	08
THMI	Thelypodium micranthum (Gray) Torr.	08
TRNE	Tragia nepetaefolia Cav.	08
TRAR	Trichostema arizonicum Gray	08
VECI	Verbena ciliata Benth.	08
VENE	Verbena neomexicana (Gray) Small	08
VENEX	Verbena neomexicana xylopoda Perry	08
VEPL	Verbena plicata Greene	08
VERO	Verbesina rothrockii Robins. & Greenm.	08
VICO	Viguiera cordifolia Gray	08
VIDE	Viguiera dentata (Cav.) Spreng.	08
VIAR	Vitis arizonica Engelm.	08
ZEPO	Zexmenia podocephala Gray	08
ZIGR	Zinnia grandiflora Nutt.	08
ZIPU	Zinnia pumila Gray	08
ACNE	Acalphya neomexicana Muell. Arg.	09
AMFI	Amaranthus fimbriatus (Torr.) Benth.	09
AMGR	Amaranthus graecizans L.	09
AMPA 1	Amaranthus palmeri Wats.	09
AMVI	Amaranthus viridis L.	09
ANCR	Anoda cristata (L.) Schlecht.	09
ATEL	Atriplex elegans (Moq.) D. Dietr.	09
BILE	Bidens leptocephala Sherff	09
BOCO 1	Boerhaavia coulteri (Hook. F.) Wats.	09
BOER 1	Boerhaavia erecta L.	09
CALE 1	Cassia leptadenia Greenm.	09
CALI	Cassia lindheimeriana Scheele	09
CAIN	Castilleja integra Gray	09
CRPU	Crotalaria pumila Ortega	09
CRAL	Cryptantha albida (H. B. K.) Johnst.	09
CUCA	Cuscuta campestris Yuncker	09
DALE	Dalea lemmonii Parry	09
DITE	Diodia teres Walt.	09
DRTE	Drymaria tenella Gray	09
ERIGE	Erigeron sp.	09

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
ERCA	Erigeron canadensis L.	09
ERDI 1	Erigeron divergens Torr. & Gray	09
EROR	Erigeron oreophilus Greenm.	09
ERAB	Eriogonum abertianum Torr.	09
ERDE	Eriogonum deflexum Torr.	09
ERPO	Eriogonum polycladon Benth.	09
EUDE	Euphorbia dentata Michx.	09
EUDEC	Euphorbia dentata cuphosperma Engelm.	09
EUEX	Euphorbia exstipulata Engelm.	09
EUHE	Euphorbia heterophylla L.	09
EUHY	Euphorbia hyssopifolia L.	09
EUIN	Euphorbia indivisa (Engelm.) Tidestrom	09
EUMI	Euphorbia micromera Boiss.	09
EURE	Euphorbia revoluta Engelm.	09
EUSE 1	Euphorbia serpyllifolia Engelm.	09
EUSE 2	Euphorbia serrula Engelm.	09
EUSE	Euphorbia setiloba Engelm.	09
FRGR	Froelichia gracilis (Hook.) Moq.	09
GONI	Gomphrena nitida Rothr.	09
HAGR	Haplopappus gracilis (Nutt.) Gray	09
HEAN	Helianthus annuus L.	09
HEPH	Heliotropium phyllostachyum Torr.	09
HEPI	Heterosperma pinnatum Cav.	09
HESU	Heterotheca subaxillaris (Lam.) Britt. & Rusby	09
HYWI	Hymenothrix wislizenii Gray	09
IPCA	Ipomoea cardiophylla Gray	09
IPCO	Ipomoea coccinea L.	09
IPCO 1	Ipomoea costellata Torr.	09
IPMU	Ipomoea muricata Cav.	09
IVAM	Iva ambrosiaefolia Gray	09
KAGR	Kallstroemia grandiflora Torr.	09
LETH	Lepidium thurberi Wooton	09
MEAS	Mentzelia asperula Woot. & Standl.	09
MEPU	Mentzelia pumila (Nutt.) Torr. & Gray	09
MOCE	Mollugo cerviana (L.) Seringe	09
MOVE	Mollugo verticillata L.	09
PECY	Pectis cylindrica (Fern.) Rydb.	09
PEFI	Pectis filipes Harv. & Gray	09
PEPR	Pectis prostrata Cav.	09
PHPA	Phaseolus parvulus Greene	09
PHYSA	Physalis sp.	09
POTR	Polanisia trachysperma Torr. & Gray	09
POOL	Portulaca oleracea L.	09
POPA	Portulaca parvula Gray	09
PRAR	Proboscidea arenaria (Engelm.) Decne.	09
PRPA	Proboscidea parviflora (Wooton) Woot. & Standl.	09
SAKA	Salsola kali L.	09

(Continued on next page)

Appendix Table 1. (Continued).

Alphanumeric symbol	Scientific name	Growth form
SASU	Salvia subincisa Benth.	09
SAAB	Sanvitalia abertii Gray	09
SCIN	Schistophragma intermedia (Gray) Pennell	09
SCWI	Schkuhria wislizenii Gray	09
SIEX	Simsia exaristata Gray	09
TILA	Tidestromia lanuginosa (Nutt.) Standl.	09
TRPO	Trianthema portulacastrum L.	09
TRTE	Tribulus terrestris L.	09
VEEN	Verbesina encelioides (Cav.) Benth. & Hook.	09
VIGUI	Viguiera sp.	09
VIAN	Viguiera annua (Jones) Blake	09
VIMU	Viguiera multiflora (Nutt.) Blake	09
XASA	Xanthium saccharatum Wallr.	09
NOSI	Notholaena sinuata (Log.) Kaulf.	10
NOSIC	Notholaena sinuata cochisensis (Goodding) Weatherby	10

Growth forms: 01, Trees; 02, Shrubs; 03, Cacti; 04, Agaves and related; 05, Perennial grasses; 06, Annual grasses; 07, Grasslike; 08, Perennial forbs; 09, Annual forbs; and 10, Cryptogams.

Appendix Table 2. Summary of the stepwise discriminant analysis.

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
Association M	Group 1	A	12	1	Ledu[2]
(Mortonia scabrella)		B	12	2	Acco
				3	Opph[1,3]
	Subgroup 2	1A	9	1	Ledu
		1B	3	2	Acco
		2C	7	3	Teco
		2D	5	4	Eypo[2]
				5	Trgr
				6	Trar
				7	Leco
				8	Potr[1]
				9	Mumi
				10	Mupa
				11	EPHED
				12	Bohi[3]
Association J					
(Cnidoscolus angustidens)	Group 1	A	6	1	Hico[2]
		B	20	2	Muar 2
				3	Aymi
				4	Hacr 1
				5	Argl 1
				6	Paha[3]
	Subgroup 2	1A	6	1	Arad
		2B	16	2	Agpa
		2C	4	3	Hico[2]
				4	Muar 2
				5	Argl 1
				6	Hacr[1,3]
Association L					
(Agave palmeri-Agave parryi/ Haplopappus laricifolius)	Group 1	A	20	1	Brve
		B	14	2	Bohi[2]
		C	14	3	Trmo
				4	Elba
				5	Agpa
				6	Dawh
				7	Hibe
				8	Bocu
				9	Anto
				10	Hala
				11	Eypo
				12	Acco
				13	Lyph
				14	Vico
				15	Sasu
				16	Pain
				17	Boro

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Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				18	Basa
				19	Heco
				20	Arba
				21	Yuel
				22	Dale
				23	Himu
				24	Boar
				25	Pahi
				26	Goca
				27	Prju
				28	Erwr[1]
				29	Agpa 1
				30	Move[3]
	Subgroup 2	1A	8	1	Prju
		1B	6	2	Brve
		1C	6	3	Yuel
		2D	9	4	Krpa
		2E	5	5	Sasu
		3F	7	6	Bohi
		3G	7	7	Pahi
				8	Arad
				9	Anci
				10	Mibi
				11	Goca
				12	Dale
				13	Hibe
				14	Hala
				15	Agpa
				16	Lyph
				17	Anto
				18	Boar
				19	Pain[2]
				20	Gusa
				21	Deco
				22	Dawh
				23	Heco[1]
				24	Trmo[3]
Association F (Gilia rigidula–Rhynchosia texana) and Association H (Haplopappus tenuisectus/ Eragrostis lehmanniana)	Group 1	A	16	1	Caba[2]
		B	13	2	Eptr
				3	Giri[1]
				4	Teco
				5	Dana
				6	Ende
				7	Paha
				8	Muar 1
				9	Pore

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Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step. no.	Species used in the SDA
				10	Boer
				11	Baab
				12	Caba[4]
				13	Evpi
				14	Boro
				15	Prju
				16	Rhte
				17	Hate
				18	Hibe
				19	Spcr
				20	Alin
				21	Bogr
				22	Boro[4]
				23	Arpa
				24	Oxla
				25	Arlo
				26	Evar
				27	Yuel
				28	Crco
				29	Soel
				30	Brde
				31	Arba[3]
	Subgroup 2	1A	7	1	Caba
		1B	9	2	Spco
		2C	9	3	Eptr
		2D	4	4	Giri
				5	Paha
				6	Erle
				7	Crco
				8	Ende
				9	Yuel[1,2]
				10	Muar 1
				11	Pore
				12	Chco 1
				13	Evpi
				14	Boch
				15	Arpa
				16	Hodr
				17	Arlo
				18	Boro
				19	Erpu
				20	Alin
				21	Rhte
				22	Coer
				23	Arba
				24	Brde
				25	Baab[3]

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Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
Association G	Group 1	A	12	1	Erwr
(Hilaria mutica/Eriochloa gracilis/		B	12	2	Boer[2]
Crotalaria pumila),		C	16	3	Arwr
Association E				4	Himu
(Hilaria belangeri), and				5	Crpu
Association D				6	Ampa 1[1,3]
(Menodora scabra/Tridens grandiflorus)	Subgroup 2	1A	7	1	Erwr
		1B	5	2	Euse 1
		2C	7	3	Boer
		2D	5	4	Arwr
		3E	9	5	Goca
		3F	7	6	Crpu
				7	Crco
				8	Argl 1[1,2]
				9	Eual
				10	Zipu
				11	Vero
				12	Trgr[3]
Proportionate random sample	Group 1	A	14	1	Agpa 1
		B	13	2	Acco
		C	10	3	Flce[2]
				4	Latr
				5	Zipu
				6	Pena
				7	Nomi
				8	Krpa
				9	Himu
				10	Paha
				11	Deco
				12	Spcr[1,3]
	Subgroup 2	1A	7	1	Paha
		1B	7	2	Agpa 1
		2C	5	3	Deco
		2D	4	4	Muar 1
		2E	4	5	Evar
		3F	5	6	Spgr
		3G	5	7	Acco
				8	Zipu
				9	Dale
				10	Hibe
				11	Arlo
				12	Dawh
				13	Arte
				14	Boch
				15	Bapt
				16	Pool

(Continued on next page)

Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				17	Ardi
				18	Erwr
				19	Evse
				20	Heco
				21	Spcr[1]
				22	Arpa
				23	Evpi
				24	Erab[2, 3]
Association E (Hilaria belangeri) and Association D (Menodora scabra/Tridens grandiflorus)	Group 1	A	22	1	Trmu
		B	24	2	Zipu
		C	20	3	Goca[2]
				4	Hate
				5	Dype
				6	Euhy
				7	Kagr
				8	Nein
				9	Hibe
				10	Bapt
				11	Arad
				12	Pool
				13	Erwr
				14	Lypa
				15	Move
				16	Trgr
				17	Chco 1
				18	Dafo
				19	Flce
				20	Yuba
				21	Oxla
				22	Soel
				23	Gusa
				24	Arpa
				25	Dale
				26	Ciwh
				27	Sasu
				28	Mesc
				29	Evse
				30	Lyph
				31	Hasp
				32	Arpu 1
				33	Boch
				34	Latr
				35	Trpo
				36	Agpa[1, 3]
	Subgroup 2	1A	14	1	Move
		1B	5	2	Lypa

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Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
		1C	3	3	Goca
		2D	12	4	Trar
		2E	4	5	Gusa
		2F	8	6	Trmu
		3G	11	7	Zipu
		3H	5	8	Mibi
		3I	4	9	Chco 1[2]
				10	Oxla
				11	Latr
				12	Hate
				13	Leco
				14	Trpo
				15	Hasp
				16	Nein
				17	Dale
				18	Arad
				19	Dafo
				20	Dype
				21	Euhy
				22	Soel
				23	Boch
				24	Kagr
				25	Agpa
				26	Mupo
				27	Lyph
				28	Ciwh
				29	Mesc
				30	Flce
				31	Yuba
				32	Arpu 1
				33	Pool
				34	Arpa
				35	Erwr
				36	Evse
				37	Spgr
				38	Bapt
				39	Sasu
				40	Hibe
				41	Sema[3,5]
Association B					
(*Rhus microphylla*-	Group 1	A	10	1	Erab
Dalea formosa)		B	14	2	Abin
		C	10	3	Ardi
		D	15	4	Boch
		E	11	5	Arad
				6	Mele
				7	Eure[2]

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Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				8	Krpa
				9	Eual
				10	Hode
				11	Zigr
				12	Flce
				13	Arpa
				14	Opsp
				15	Evse
				16	Stem
				17	Kagr
				18	Fosp
				19	Mesc
				20	Cosp
				21	Pest
				22	Paha
				23	Hodr
				24	Ople
				25	Spco
				26	Dawh
				27	Arpu 1
				28	Lefe
				29	Kosp
				30	Pewr
				31	Dyac
				32	Ipco 1[1]
				33	Apun
				34	Euse 1
				35	Coca
				36	Latr[3]
	Subgroup 2	1A	7	1	Erab
		1B	3	2	Ardi
		2C	9	3	Dawh
		2D	5	4	Eual
		3E	5	5	Abin
		3F	5	6	Boch
		4G	9	7	Arad
		4H	6	8	Stem
		5I	8	9	Mele
		5J	3	10	Evse
				11	Caer
				12	Ipco 1
				13	Coca
				14	Coer
				15	Dine
				16	Pest
				17	Eure
				18	Ople

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Appendix Table 2. (Continued)

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				19	Krpa
				20	Spco
				21	Lefe
				22	Flce
				23	Latr
				24	Cosp
				25	Fosp
				26	Mesc
				27	Zigr
				28	Hode
				29	Kagr
				30	Kosp
				31	Arpu 1
				32	Gusa
				33	Hodr[1]
				34	Thte
				35	Arpa
				36	Dyac[2, 3]
Association A					
(*Panicum hirticaule*/*Tidestromia lanuginosa*-*Boerhaavia coulteri*)	Group 1	A	49	1	*Dafo*[2]
		B	20	2	*Bocu*[4]
and Association B				3	Eure
(*Rhus microphylla*-*Dalea formosa*)				4	Atca
				5	Baab
				6	Colyc
				7	Moce
				8	Taau
				9	Abin
				10	Acve
				11	Spwr
				12	Coer[4]
				13	Dapo
				14	Pain
				15	Nomi
				16	Latr
				17	Jagr
				18	Trne
				19	Zipu
				20	Hyve
				21	Bocu[4]
				22	Iphe
				23	Popa
				24	Eumi
				25	Pool
				26	Move
				27	Boar
				28	Soel

(Continued on next page)

Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				29	Vero
				30	Ampa 1
				31	Boer
				32	Dine
				33	Chco 1
				34	Euse 2
				35	Dica
				36	Paar
				37	Amfi
				38	Flce[1]
				39	Spwr[4]
				40	Thte[3]
	Subgroup 2	1A	33	1	Dafo
		1B	16	2	Soel
		2C	15	3	Dapo[2]
		2D	5	4	Abin
				5	Acve
				6	Amfi
				7	Dica
				8	Zipu
				9	Popa
				10	Latr
				11	Ipco 1
				12	Coer
				13	Atca
				14	Boar
				15	Baab
				16	Eure
				17	Hyve
				18	Thte
				19	Dine
				20	Euse 2[1]
				21	Trne
				22	Pain
				23	Moce
				24	Move[3]
Association I (Ayenia pusilla/Eragrostis intermedia), and The Variant 1a	Group 1	A	16	1	Eypo
		B	13	2	Fosp[2]
		C	13	3	Bapt
				4	Dawh
				5	Hico
				6	Caer
				7	Hide
				8	Sili
				9	Boel
				10	Pena[1]

(Continued on next page)

Appendix Table 2. (Continued).

Classification unit	Hierarchical level	Descriptor	No. of stands	Step no.	Species used in the SDA
				11	Erpu
				12	Saab[3]
	Subgroup 2	1A	5	1	Saab
		1B	6	2	Dawh
		1C	5	3	Hico
		2D	8	4	Sapa
		2E	5	5	Caer
		3F	7	6	Sili
		3G	6	7	Boar
				8	Eypo
				9	Acgr
				10	Agpa 1
				11	Yuel
				12	Pena[1,2,3]

[1] Number of species required to achieve a perfect discrimination between and among groups and/or subgroups.

[2] Number of species required to achieve significance at .01 probability when the groups and/or subgroups were compared in a pairwise fashion.

[3] Number of species used to calculate the canonical variables.

[4] Attributes removed at the steps indicated.

[5] No perfect discrimination was reached. The entrance of Sema into the scheme did not change the classification matrix since the same stand was misclassified in subgroup 2F.

The underlined alphanumerical symbols refer to species that were differential for groups and subgroups.

Appendix Table 3. Key to the vegetational units of the Tombstone, Arizona, vicinity.

1a	Grass prominent, with or without scattered shrubs	2
2a	Yucca elata and Bouteloua eriopoda the most prominent species--Alliance II (YUCCA ELATA/BOUTELOUA ERIOPODA)	3
3a	With Menodora scabra and Tridens grandiflorus--Association D (MENODORA SCABRA/TRIDENS GRANDIFLORUS)	
3b	Without Menodora scabra and Tridens grandiflorus	4
4a	With Hilaria belangeri in relative dense uniform stands--Association E (HILARIA BELANGERI)	
4b	Without Hilaria belangeri or if present in small patches	5
5a	With Gilia rigidula and Rhynchosia texana--Association F (GILIA RIGIDULA-RHYNCHOSIA TEXANA)	
5b	Without Gilia rigidula and Rhynchosia texana but with Gutierrezia sarothrae and Eriogonum abertianum--Association C (GUTIERREZIA SAROTHRAE/ERIOGONUM ABERTIANUM)	
2b	Yucca elata and Bouteloua eriopoda are not the most prominent species. If present, very scattered.	6
6a	With Agave palmeri, Agave parryi and Haplopappus laricifolius--Association L (AGAVE PALMERI-AGAVE PARRYI/HAPLOPAPPUS LARICIFOLIUS)	
6b	Without Agave palmeri, A. parryi and Haplopappus laricifolius	7
7a	With Hilaria mutica, Eriochloa gracilis, and Crotalaria pumila--Association G (HILARIA MUTICA/ERIOCHLOA GRACILIS/CROTALARIA PUMILA)	
7b	Without Hilaria mutica, Eriochloa gracilis, and Crotalaria pumila but with Haplopappus tenuisectus and Eragrostis lehmanniana--Association H (HAPLOPAPPUS TENUISECTUS/ERAGROSTIS LEHMANNIANA)	
1b	Grasses not prominent, shrubs the most prominent.	8
8a	Acacia vernicosa, Larrea tridentata, and Flourensia cernua the most prominent species. Low grass cover--Alliance I (ACACIA VERNICOSA-LARREA TRIDENTATA-FLOURENSIA CERNUA)	9
9a	With Rhus microphylla and Dalea formosa. In addition, Yucca baccata and Nolina microcarpa--Association B (RHUS MICROPHYLLA-DALEA FORMOSA)	
9b	Without the above species, or if present scattered, but with the annuals Panicum hirticaule, Tidestromia lanuginosa and Boerhaavia coulteri--Association A (PANICUM HIRTICAULE/TIDESTROMIA LANUGINOSA-BOERHAAVIA COULTERI)	

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Appendix Table 3. (Continued).

8b *Acacia vernicosa*, *Larrea tridentata*, and *Flourensia cernua* are not the prominent species. Grass cover abundant.	10
10a With *Fouquieria splendens*, *Acacia constricta* and *Aloysia wrightii*--Alliance III (*FOUQUIERIA SPLENDENS-ACACIA CONSTRICTA-ALOYSIA WRIGHTII*)	11
11a With *Cnidoscolus angustidens* or *Ayenia pusilla* and *Eragrostis intermedia*	
12a With *Cnidoscolus angustidens*--Association J (*CNIDOSCOLUS ANGUSTIDENS*)	
12b Without *Cnidoscolus angustidens* but with *Ayenia pusilla* and *Eragrostis intermedia*--Association I (*AYENIA PUSILLA*/*ERAGROSTIS INTERMEDIA*)	
11b Without *Cnidoscolus angustidens* or *Ayenia pusilla* and *Eragrostis intermedia*--Association K (TYPICAL ASSOCIATION)	
10b Without *Fouquieria splendens*, *Acacia constricta*, and *Aloysia wrightii* but with *Mortonia scabrella*-Association M (*MORTONIA SCABRELLA*)	