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THE STATUS OF PALMER'S AGAVE AT CORONADO

NATIONAL MEMORIAL

by

Michelle Macy Hawks

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCES

In the Graduate College

THE UNIVERSITY OF ARIZONA

1997

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DEDICATION

This thesis is dedicated to my father, George H. Hawks III, a man of incredible intelligence and patience. He taught me to respect the world around me, and encouraged me to follow my own stars.

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ABSTRACT

The status of the Palmer's agave (*Agave palmeri*) population at Coronado National Memorial was determined by studying recruitment, herbivory and flowering. Data was collected during the summers of 1995 and 1996. Baseline information was found that will aide in comparisons about the population in the future. The population structure was found to have a large number of younger individuals with a high mortality rate. The older age classes had a much lower mortality rate. The affect of grazing was examined as one of the possible impacts to this specific population. There were no significant differences in recruitment, flowering or herbivory between areas exposed to grazing versus areas not exposed to grazing. Palmer's agave is a long-lived species that will require several years of monitoring its population to get a better understanding of the factors that determine its population dynamics.

INTRODUCTION

Statement of Problem

This study was conducted in response to concerns by Coronado National Memorial about the status of the Palmer's agave population present on the memorial. Little is known about the population dynamics of Palmer's agave (*Agave palmeri*). This study established a long-term monitoring program that will show population trends over time. The monitoring program may also give clues to what factors affect the population. The monitoring program goals are to track recruitment, survival, and growth of individuals through time.

Originally this study was to focus on three species of agave: Schott's agave (*Agave schotti*), Parry's agave (*Agave parryi*) and Palmer's agave. When surveying the memorial it was noted that the only species found, in sufficient numbers to study was the Palmer's agave. This observation changed the scope of the study to a focus on Palmer's agave.

Palmer's agave serves an important role in the habitats where it exists. It's nectar is an important food source for the long-tongued bat (*Choeronycteris mexicana*) and lesser long-nosed bat (*Leptonyteris curasoae*), two bat species present at the memorial. The lesser long-nosed bat is federally listed as endangered. Hummingbirds also drink the nectar produced by the flowers. Herbivores such as cattle, white-tailed deer (*Odocoileus virginianus*), and small rodents eat the newly emergent flowering stalks of the plant. A photo of a chewed flowering stalk is shown in Figure 1. The percentage of flowering

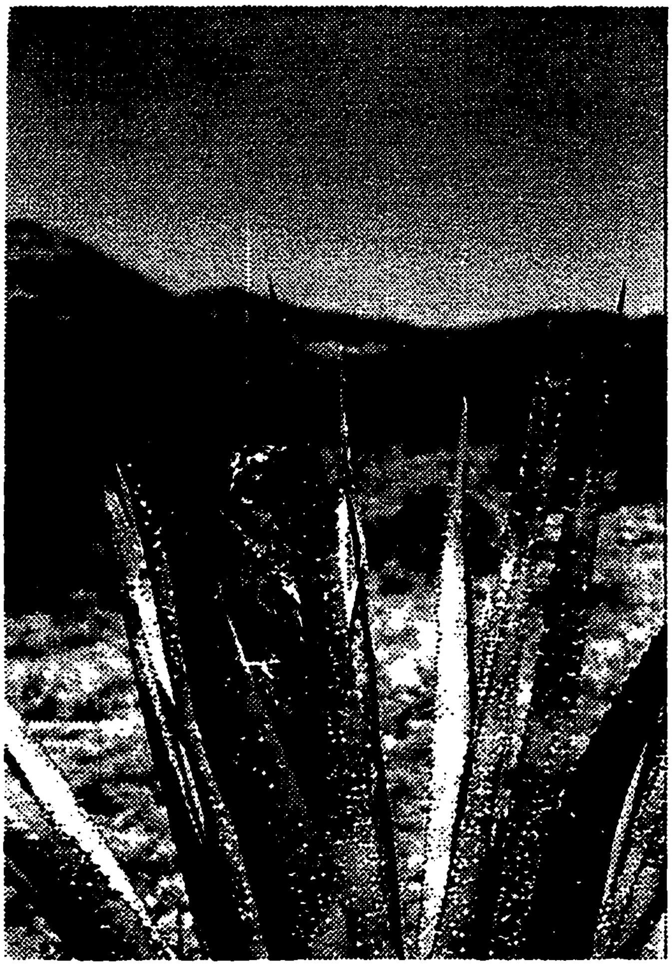


Figure 1. An *Agave palmeri* with flowering stalk completely chewed off.

stalks chewed is one of the factors being looked at in the monitoring program. Many different insects also use this plant, the sonoran bumblebee (*Bombus sonorus*), the agave weevil (*Scyphophorus acupunctatus*) and spiders in the families *Salticidae* and *Lycosidae* (Waring and Smith 1987). Waring and Smith (1987) observed what could be thought of as a miniature ecosystem living and dependent on Palmer's agave.

Cattle grazing occurs on the memorial. With the recognition of the importance of Palmer's agave the memorial was concerned that there might be negative effects from grazing on the population. A survey of possible effects by cattle was also included in the monitoring program. Trampling and herbivory damage by cattle were the focus of this part of the study. Trampling by cattle could be detrimental where there are large numbers of animals stocked in a small area. The more animals there are, the greater the chance that a young individual could get trampled. Both cattle and wildlife eat the flowering stalks of the agave. It is unknown how much herbivory is due to cattle versus the native wildlife. However, it was thought that the extra herbivore present at Coronado added stress on the plant population.

Studies by Hodgeson and DeLamater (1988) and Martinez-Morales and Meyer (1985) both found grazing to be detrimental to populations of Arizona agave (*Agave arizonica*) and marguay verde (*Agave salmiana* ssp. *crassispina).* Cattle ate flowering stalks and trampled young individuals. The high concentration of animals in a confined space also caused soil compaction. The herbivory by cattle impacted plant reproduction whereas soil compaction and trampling affected the ability of young individuals to establish and grow. The studies concluded that all three impacts of cattle grazing affect the size of future populations. Both studies failed to mention stocking rates.

The monitoring program is designed to show trends in the Palmer's agave population over time. It will be important for Coronado National Memorial staff in establishing their grazing management plan to know how the grazing is affecting this natural resource. The information from the monitoring program will also give managers at the memorial as well as elsewhere some insight into what affects the plants and how their populations develop through time. The goal of this initial study is to determine the current status of Palmer's agave. The data resulting from this study can then be used for comparison with data collected in the future.

Study Objectives

1. Set up a long-term monitoring program to look at population trends of Palmer's agave at Coronado National Memorial.

2. Determine average fruit set of the population at Coronado National Memorial.

3. Determine the extent of herbivore stalk predation damage on Palmer's agave by white-tailed deer, cattle and small rodents and determine if this predation affects the populations at Coronado National Memorial and Ft. Huachuca.

4. Determine the direct effects of cattle on Palmer's agave populations at Coronado National Memorial.

5. Develop a GIS database for Coronado National Memorial, that will include layers for roads, the boundary, vegetation, monitoring plot points, and other features as appropriate.

Background

Palmer's agave is distributed throughout Southern Arizona and Northern Sonora, Mexico (Figure 2). It occurs in oak woodland and desert grassland communities at elevations between 930 meters and 1850 meters. It seems to have a patchy distribution within these communities (Gentry 1982). At Coronado National Memorial more Palmer's agave were observed on south facing slopes where fewer oaks and juniper are found.

Agaves are succulents with CAM (crassulacean acid metabolism) photosynthesis. The leaves are arranged in a rosette formation. They are guttered to channel water toward the base of the plant. The margins of the leaves are lined with narrow teeth and the leaves terminate in a slender spine. These are thought to be part of the plant's defense against herbivory. Palmer's agave leaves are long lanceolate with close-set slender spines, sometimes with smaller spines in between (Gentry 1982). Agaves are classified as monocarpic perennials due to their reproductive strategy of flowering once after many years then dying (Howell and Roth 1981). Palmer's agave takes 15 to 20 years to flower. A flowering stalk, 5-7 meters tall, is sent straight up from the middle of the leaf rosette. The flowering stalk branches and forms panicles in its upper third. The flowers are pale greenish yellow to a waxy white (Gentry 1972, Gentry 1982, Nobel 1988).

Agaves have high aesthetic and economic value. Many species are used as ornamentals in landscaping or cultivated for fibers, tequila and mescal production (Breitung 1968, Gentry 1972). Agaves have been associated with humans for about 9000

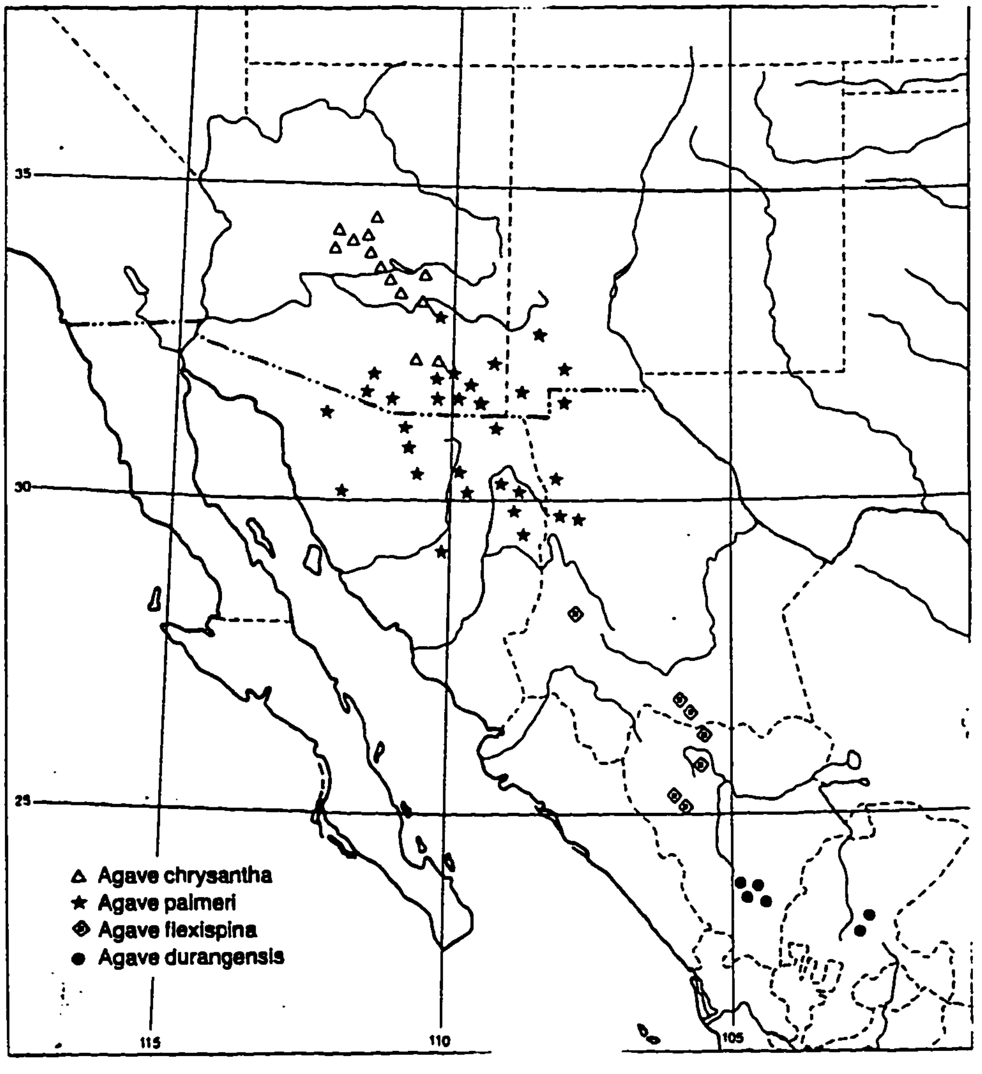


Figure 2. Distribution of Palmer's Agave in Southern Arizona and Sonora, Mexico. The figure was taken from Gentry (1982).

years. Species were taken overseas for ornamentals and are distributed throughout Europe. Plantations were created in the Philippines, Indonesia and East Africa for the production of fiber. Agaves have been important to the native people of the Southwestern United States and Mexico. They used the plants for food, drink and many different tools. It is thought to be one of the original cultivated plants in its native area. Horticultural use of agaves lead to expansion of the range of many species. It is suspected that some species radiation is due to human cultivation and cross pollination for more desirable varieties (Gentry 1982, Nobel 1988). Palmer's agave was used by native people of the area and has been known to be collected for mescal. There is little reference to any intensive cultivation of Palmer's agave at present (Gentry 1982, McDaniel 1985, Nobel 1988).

Palmer's agave puts the majority of its energy into reproduction. About sixty percent of the plant's biomass at the time of flowering is redirected to reproduction (Howell and Roth 1981). During the 15 to 20 years of vegetative growth the plant is mostly accumulating energy for its reproductive event. When flowering starts photosynthesis can not keep up with the energy drain. During flowering, water and nutrients that have been accumulated in the leaves and bole (or central part of the plant) are transferred to the stalk and flowers (Howell and Roth 1981, Gentry 1982). The energy transfer results in death after reproduction. Through horticultural practices people have found that agaves can be kept alive a few years longer if the flowering stalk is clipped just as it starts to form. The plant will never send up another flowering stalk and may not even vegetatively reproduce (Liz Slauson Personal Communication, 1996).

Palmer's agave studies have been limited in scope, only covering a few aspects of the species' life history. There have been a few studies on the adaptation to arid environments by agave. These studies included water and temperature tolerances of agave (Freeman 1975, Nobel 1984, Burgess 1985). The mechanisms of CAM photosynthesis have also been looked at by Nobel and McDaniel (1984) and Nobel (1985).

Howell 1978, Howell and Roth 1981, Schaffer and Schaffer 1977, and Slauson 1996, conducted studies addressing the relationships between Palmer's agave and its pollinators. The lesser long-nosed bat has been studied extensively. It was believed that there was a mutualistic relationship between the bat and Palmer's agave. The evidence presented was the strong smell of the flowers that attracts bats, and the majority of the nectar production occurring at night (Howell 1978). The study by Schaffer and Schaffer (1977) showed that the flower structure made it possible for other potential pollinators to obtain the nectar without touching the reproductive parts of the flower.

A study by Liz Slauson (Desert Botanical, Phoenix, AZ) is in progress to determine the importance of bats as pollinators of Palmer's agave. Other pollinators such as European honeybee (*Apis mellifera*), sonoran bumblebee, carpenter bees (*Xylocopa arizonensis*), hawkmoths (*Mandura spp.*), and hummingbirds also visit the flowers (Slauson 1995 personal communication). Although Howell and Roth (1981) concluded that the bats are primary pollinators of Palmer's agave there are areas where Palmer's agave continue to grow and reproduce in the absence of bats. It is uncertain how important a role the bats play in agave reproduction, but the agave is an important habitat component for the bats.

There have been a few studies that have looked at the human effects on the Agave genus. A few studies have looked at the effects of the mescal industry on a few species (Martinez-Morales and Meyer 1985, Tello-Balderas and Garcia-Moya 1985). Intense grazing in agave habitat was found to reduced the survival of Arizona agave (*Agave arizonica*) and marguay verde (*Agave salmiana* ssp. *crassispina*) (Hodgeson and DeLamater 1988, Martinez-Morales and Meyer 1985). No articles have addressed if there are any effects of grazing on Palmer's agave.

Habitat destruction due to development and grazing may threaten Palmer's agave populations in some areas (Gentry 1972). There is limited knowledge on the species micro-environmental needs and other limiting factors that could regulate the populations.

METHODS

Study Area

The majority of this research was done in Coronado National Memorial. The memorial is located 37 kilometers south of Sierra Vista, Arizona, at the southern end of the Huachuca Mountains (Figure 3). The memorial is 2,013 hectares in size. Its northern and western boundaries are shared with Coronado National Forest, and the southern boundary is the United States-Mexican border. The eastern boundary is next to private land. Coronado National Memorial consists of the entire Montezuma Canyon Watershed which eventually drains into the San Pedro River. There are two grazing allotments on Coronado National Memorial, Joe's Spring and Montezuma. Joe's Spring has been under the same permittee since 1940. It is 553 hectares with 54 cattle stocked from mid-November to mid-July. That equals 432 AUMs. The Montezuma allotment has changed permittees several times. It is 332 hectares and has not been grazed since February of 1990. At that time the stocking rate was 76 cattle between Mid-October and the end of February, that is equal to 342 AUMs.

The vegetation present is typical of the southeastern Arizona mountains. Ruffner and Johnson (1991) found four biotic communities present at the memorial. The most extensive is the Oak-Mexican Pinyon Pine-Juniper Woodland Association. Typical species are Arizona white oak (*Quercus arizonica*), Emory oak (*Q. emoryi*), Mexican blue oak (*Q. oblongifolia*), alligatorbark juniper (*Juniperus deppeana*), pinyon pine *(Pinus*

Location of Coronado National Memorial

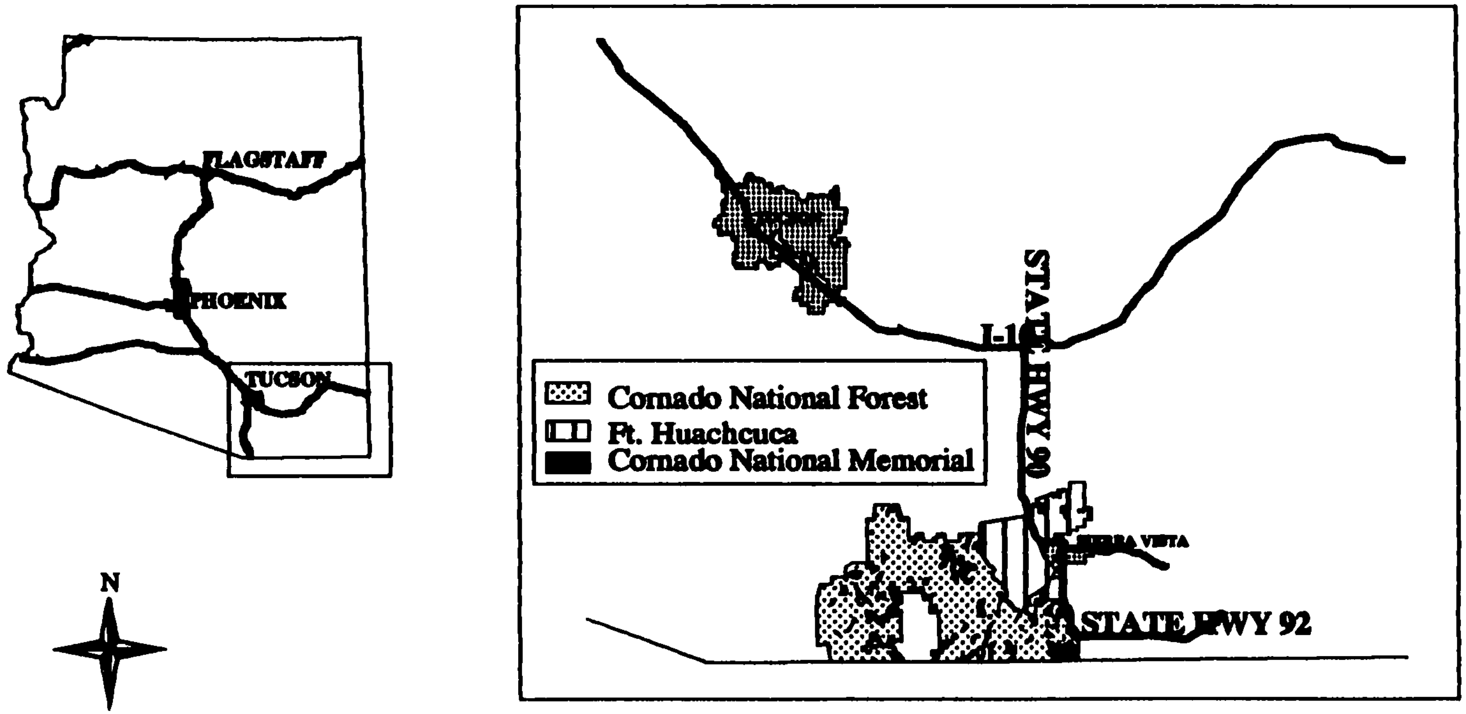


Figure 3. Location of Coronado National Memorial. The Memorial is shown in black, and Ft. Huachuca is shown in a striped pattern.

edulis) mountain mahogany (*Cercocarpus montanus*), manzanita (*Arctostaphylos spp.*), bear grass (*Nolina microcarpa*), desert spoon (*Dasylirion wheeleri*), and side oats grama (*Bouteloua curtipendula*). The eastern third of the memorial is comprised of the Grama Grass (*Bouteloua spp.*)-Mixed Grass-Mixed Shrub Grassland Association. Some of the typical species present include fairy duster (*Calliandra eriophylla*), rabbit bush (*Chrysothamnus nauseosus*), hedgehog cactus (*Echinocereus pectinatus*), Palmer's agave, blue grama (*Bouteloua gracilis*), and Lehmann lovegrass (*Eragrostis lehmanniana*), an introduced exotic. There are also Arizona white oak, Emory oak, and honey mesquite (*Prosopis glandulosa*) scattered throughout this area.

The other two communities are riparian communities. One is the Western Honey Mesquite-Mixed Short Tree Woodland Association. This community occurs in the eastern third of the memorial. It includes Arizona white oak, desert willow (*Chilopsis linearis*), Emory oak, honey mesquite, poison ivy (*Rhus radicans*), rabbit bush, cane cholla (*Opuntia spinosior*), Lehmann lovegrass, and side oats grama. The other riparian community is the Arizona Sycamore (*Plantanus wrightii*)-Arizona Walnut (*Juglans major*)-Oak Riparian Forest Association. In the memorial it is present in middle and upper Montezuma Canyon. The typical species include Arizona white oak, Arizona rosewood (*Vauquelinia californica*), Arizona Sycamore, catclaw acacia (*Acacia greggii*), manzanita, brickellia (*Brickellia spp.*), wild grape (*Vitis arizonica*), and needle grass (*Stopper spp.*).

Monitoring Plots

Nine monitoring plots (Figure 4) were set up within and adjacent to grazing allotments in Coronado National Memorial. Grazing has occurred on all the areas where plots are located. Plots one through four were last grazed in 1990. Plot five last had cattle on it in 1986. Plots six through nine are currently grazed. The areas where plots are located have a slope class of 0-10 degrees (Ogden 1995). The soil type is a Whitehouse gravelly loam. Ogden (1995) described this type as well-drained and greater than 60 inches in depth. The surface is brown gravelly loam with subsurface layers of reddish brown, dark red, and mottled red or yellowish red and pink. The textures are gravelly, sandy clay loam, clay loam, and clay.

Two plots were also located at Ft. Huachuca. Ft. Huachuca is located on the eastern side of the Huachuca mountains, adjacent to the town of Sierra Vista, (Figure 3). It is an Army base, used for military training. There are some areas on the base that are impacted by human activity such as artillery fire and armored vehicle exercises. These maneuvers do occur where Palmer's agave exists. The biggest perceived threat to Palmer's agave at Ft. Huachuca is not the maneuvers themselves, but fires that are started during military maneuvers (Howell 1995). A five year study was finished by Howell during the summer of 1995. It was supposed to determine whether fire was a threat to the agave population at Ft. Huachuca, however her findings were inconclusive. Grazing has not occurred on the base since 1950. The vegetation is similar to Coronado National Memorial except there is a larger amount of grassland as well as a number of canyons that run off the Huachuca Mountains. There is a large population of Palmer's agave on the

Palmer's Agave Monitoring Plot Locations at Coronado National Memorial

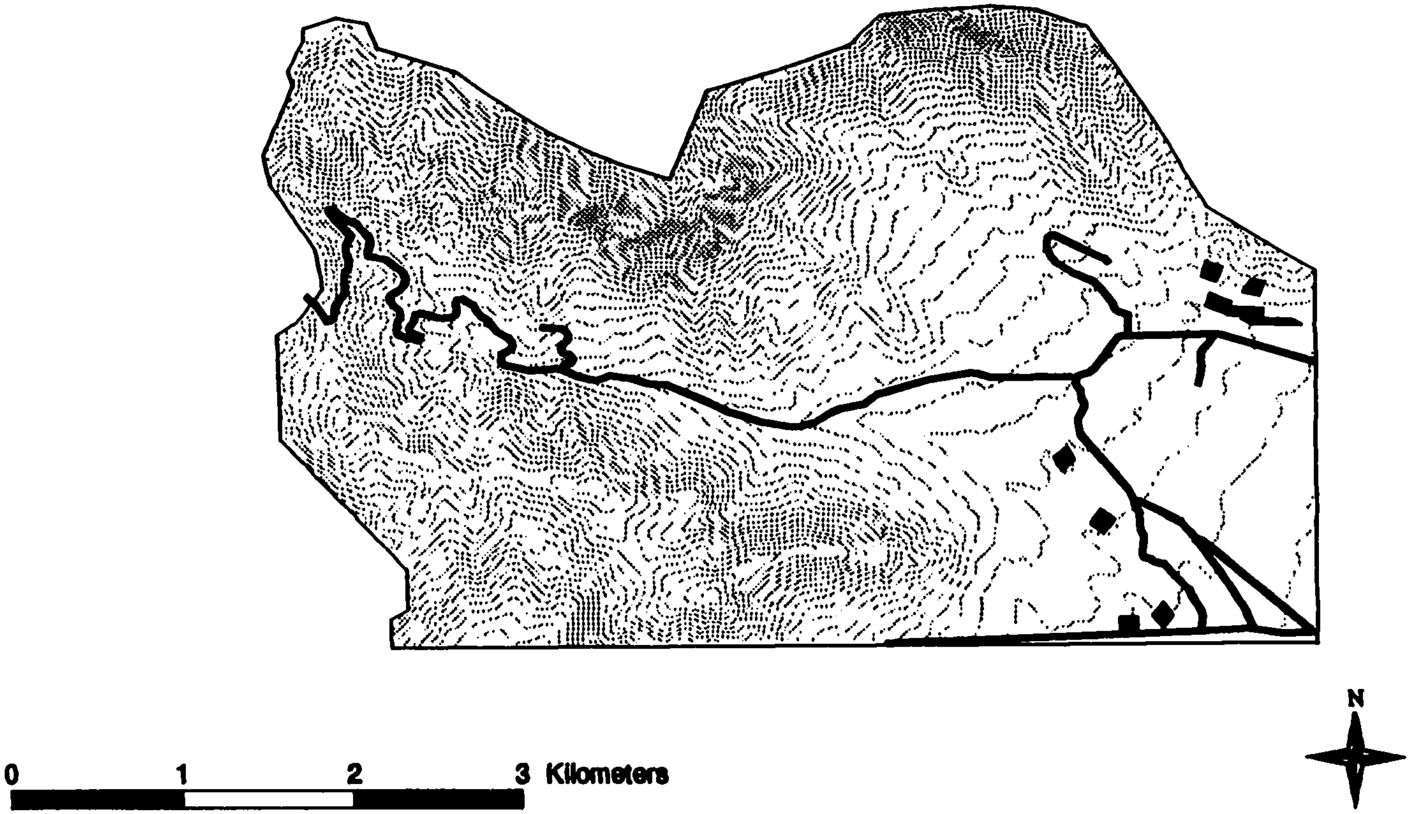


Figure 4. Location of the Palmer's agave monitoring plots used in this study. The map projection is in UTM.

base which is being monitored by base resources management personnel.

The Ft. Huachuca plots were placed in an area that was thought to be similar to the memorial. The area is not grazed, there is mild disturbance from infrequent horseback riders, there are no lethal maneuvers, such as artillery firing, occurring in the area. The elevation is 1524 meters, and the large herbivores present are white-tailed deer and javelina. The plots were square, a hectare in size, and were located along the west entrance road.

Field Survey

Plots

A long-term monitoring program was set up in cooperation with the staff of Coronado National Memorial and the Southern Arizona Group Office. Nine monitoring plots were set up at Coronado. They are one hectare (10,000 meters^2) set up in varying shapes to fit topography and locations of agave clumps used for monitoring. The plots were one hectare in order to get a substantial number of flowering plants represented each year. The plots are either square, rectangular or parallelogram. The straight edged shape allows boundaries to be easily identified when surveys are done. The plot corners are marked with rebar, and their locations are described in relation to prominent features in the landscape. Tags were attached to rebar identifying the plot number and which corner it marks.

A global positioning system (GPS) was used to get exact locations of the plots and transects within the plots. The corners of the plots were surveyed as well as the beginning and the end of each of the transects. The positions recorded from the GPS unit were be post-processed to correct for error in location due to selective availability (military scrambling of the satellite signal). The survey will help in locating the plots for long-term monitoring of agave populations at the memorial.

The monitoring plots were chosen based on a number of criteria. Palmer's agave have a clumped distribution. This made it necessary to place plots where agave patches existed versus a random distribution throughout the landscape. To determine if there were any effects of grazing, some of the plots had to be in areas where Palmer's agave were being exposed to grazing. The rest of the plots were placed outside of the areas that were grazed. The plots outside of grazed areas were supposed to be the control group. That would imply that all other factors were the same (i.e. slope, aspect, soil type, and elevation). This was attempted: Elevation of the plots is within 150 meters or less, the plots were placed in similar soil types based on soil information available at the beginning of the study, but both slope and aspect vary, somewhat. A more recent soil survey, which has yet to be completed, is likely to change the soil map. This new information is likely to indicate that the plots are not in similar types. The memorial is a small area and we were limited by where agave were found.

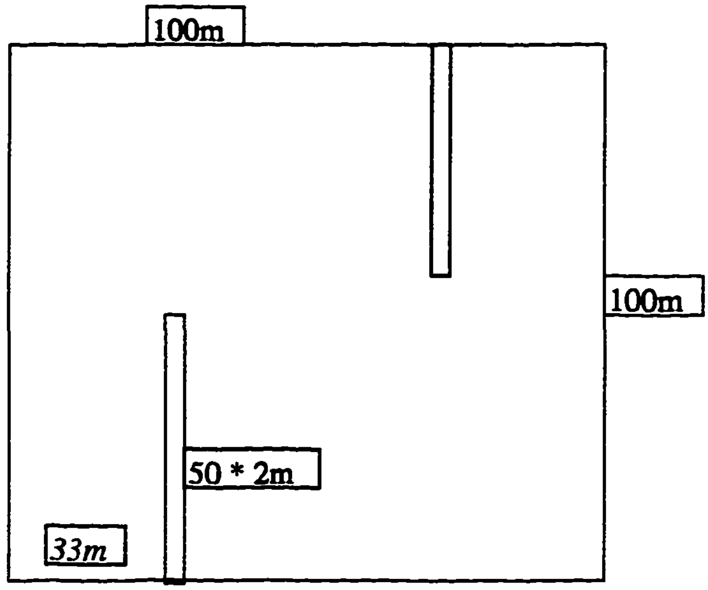
Size Class Distribution

Size class distribution data were collected both years of the study. The data collection in 1995 was done in early August and in 1996 the data were collected in early July. Size class distribution was measured by counting Palmer's agave present in transects set up in the monitoring plots. Recruitment information was also obtained from this survey. Two transects, 50 meters long and two meters wide, were set up in each plot to survey the plants. Transects were used to survey recruitment, instead of surveying the whole hectare plot, because it would be hard to make sure that a plant was not double counted. With the transects the surveyor does not walk over the same area twice. The transects were also used because it would take too long to sample the whole hectare plot. One transect uses the northern plot boundary for it's baseline the other uses the southern boundary. The transects run perpendicular to the northern and southern boundaries of the plots. In the square plots, the southern transect is 33 meters from the southwestern corner of the plot. The northern transect is 33 meters from the northeastern corner. There are two rectangular plots. The northern transects in these plots are 66 meters and 44 meters from the northeastern plot corners for the two different sized plots. The southern transects are the same distances, but from the southwestern plot corners. Finally, one plot is a parallelogram. This plot is less than 50 meters wide so there are four transects 25 meters by 2 meters. The transects from the southern boundary are 60 meters and 180 meters from the southeastern plot

corner. The transects from the northern boundary are 60 meters and 180 meters from the northeast plot corner. A diagram with transect placements is shown in Figures 5 and 6.

Size Classification

Four size classes were designated, as defined by Howell (1995 personal communication) in h research on Palmer's agave at Ft. Huachuca. Size classes were used because there is no known way



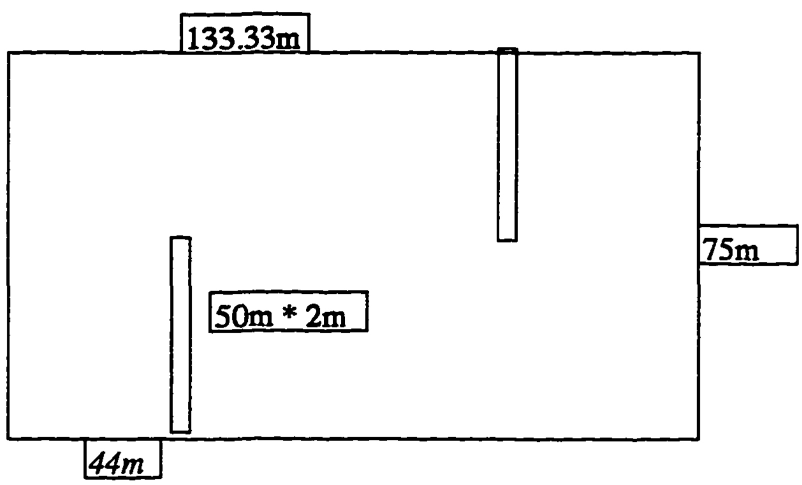
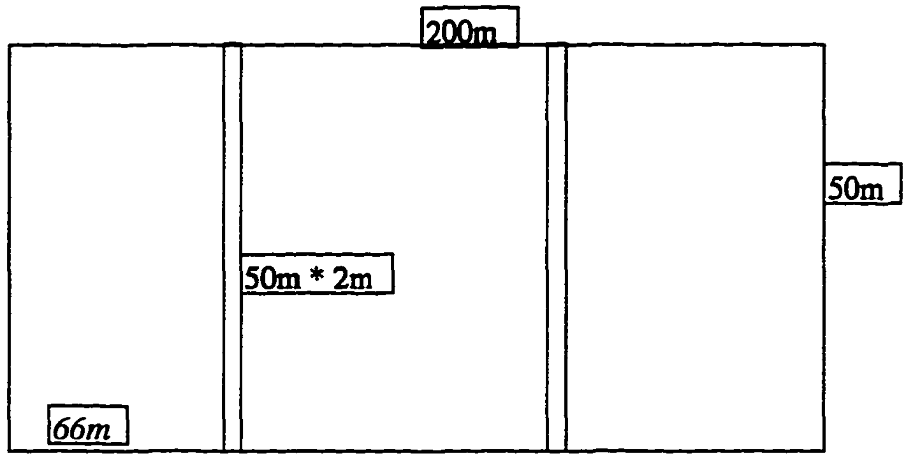


Figure 5. Layout of the transects within monitoring plots 1 - 4 and 7 - 9. Plots 1 - 4 and 8 - 9 are square like the top diagram and plot seven is represented by the bottom diagram.



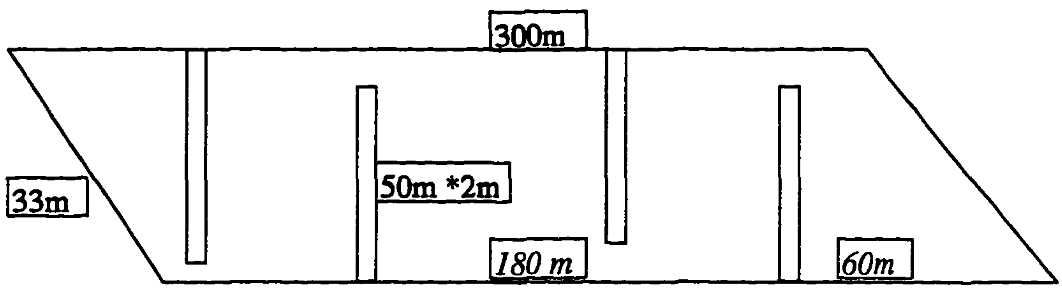


Figure 6. Layout of the transects within monitoring plots 5 and 6. Plot 5 is the top diagram and plot 6 is the bottom diagram.

of determining age of agaves. Size can not be used for a direct correlation to age, but generally the larger the plant the older it will be. Palmer's agave adds leaves in what are called Fibonacii spiral series (1,1,2,3,5,8,13,....etc.). Howell (1995 personal communication) used the determination of the number of spirals as an indicator for her four size classes. She believes that this method was more closely related to age than a size measurement such as width or height. Width and height tend to be influenced more by environmental factors than the number of leaves being formed. She has been following some plants for five years and the spirals seem to be added more regularly. The size class distinctions are as follows:

Size class 1: plants with a center leaf core or a leaf core and one leaf .

Size class 2: plants with a center leaf core and two to four leaf spirals, these leaf spirals would consist of :

-spiral 2 consists of 1 leaf

-spiral 3 consists of 2 leaves

-spiral 4 consists of 3 leaves

Size class 3: plants with a center core and five to seven leaf spirals, these spiral numbers would consist of:

-spiral 4 consists of 3 leaves

-spiral 5 consists of 5 leaves

-spiral 6 consists of 8 leaves

-spiral 7 consists of 13 leaves

Size class 4: plants that have a center leaf core and eight or more leaf spirals, this would consist of:

-spiral 8 consists of 21 leaves

Fruiting

Fruit set was also determined for the population at Coronado National Memorial. This allows the population's productivity to be compared with other populations. During August of 1995 Slauson picked fifteen plants from which she took umbels. These plants were all located in or near plot 2. The umbels from the 1995 flowering season were collected in January 1996. The number of fruits per umbel were counted. This data was collected in conjunction with Liz Slauson (Desert Botanical Garden, Phoenix). The methods are described in detail in Slauson's Ph.D. dissertation (1996). The seed set was also supposed to be determined but, was not done for this site.

Stalk Predation

The extent of stalk predation was also monitored at the end of July when the flowering stalks were no longer vulnerable to herbivores. The plants with chewed stalks were marked with a indelible pen to keep track of plants already surveyed. Flagging was tried in 1995, but cows ate the flagging that was in the grazed plots.

GIS Database

Prior to this study, there was no existing spatial database for Coronado National Memorial. Data were collected from various sources to get a set of baseline information. Three coverages were created from digitizing information from a map of the park that had been created from a former study by Ruffner and Johnson (1991). These coverages were the boundary of Coronado National Memorial, the roads, and vegetation of the park as identified by Ruffner and Johnson (1991). The other coverages were obtained from already existing data. A subset of the statewide Arizona GAP analysis vegetation was created for the area within the memorial. The 30 meter digital elevation models (DEM) for the area of the memorial were obtained as well. A contour map with 10 meter contour intervals was created from the 30 meter DEM. The coordinate locations of the monitoring plots that were obtained from GPS were made into a GIS layer also.

The GIS database created will help the memorial with future management and analysis of the park and the monitoring program data. Currently the data reside on a UNIX system at the University of Arizona, in the Advanced Resource Technology Lab, School of Renewable Natural Resources. It is planned to make these data available through the Internet along with various other spatial and non-spatial data through NBII, CPSU/UA and ART. This has not been done as of the writing of this paper.

Data Analysis

The data gathered from the field survey were, the number of plants per 200 m^2, the number of plants in each size class per 200 m^2, the number of flowering plants per hectare and the percentage of flowering plants that had flowering stalks chewed per hectare. The data presented in the results section has been extrapolated to plants/hectare. Data analysis was done to look at the general status of the population, compare whether there were any effects of grazing on the recruitment of the species, and any effects of herbivory on the species. The flowering and chewed stalk data from Ft. Huachuca was lumped with the data from non-grazed areas at the memorial. There was too little data to make a valid comparison with this data alone.

Means and standard deviations were calculated to view the data before any statistical analysis was done. The means of the data are used to describe the status of the population at the memorial. Then an analysis to compare grazing effects was done. An ANOVA was used to compare the difference between the number of plants per size class within plots exposed to grazing versus plots not exposed to grazing. The data were broken up into grazed and non-grazed, as well as by size class. The amount of flowering within plots exposed to grazing versus plots not exposed to grazing was also done. Again an ANOVA was used to compare the number of flowering plants within grazed plots with the number of flowering plants within non-grazed plots. Finally, a comparison between the percentage of flowering stalks chewed within areas exposed to grazing versus areas not exposed to grazing was done with an ANOVA.

To identify the variation within treatments (grazed or non-grazed), a comparison of the number of individuals within each size class was done within the areas that were non-grazed and within the areas that were grazed. The null hypothesis was that there was no difference between the plots within these separate treatments. This would mean that all the plots being compared were under similar conditions. A two-way ANOVA was done for this comparison. A two-way ANOVA was done on the flowering data and the chew stalk data within non-grazed plots and within the grazed plots.

RESULTS

General Population Descriptions

Based on two years of data, the average distribution of size classes was found to be: class 1 (smallest) = 1320 plants/ha, class 2 = 1215 plants/ha, class 3 = 185 plants/ha, class 4 = 170 plants/ha. A graph showing the distribution of size classes within the population is shown in Figure 7. The percentages of plants representing each size class were as follows: class 1 = 45.6%, class 2 = 41.9%, class 3 = 6.6%, class 4 = 6.0%. The total number of plants per hectare was 2895. There was some variation of number of individuals between plots and years, this is shown in Table 1. The variation between years were compared, and no significant difference was found, yet there are a few instances where there seem to be some noticeable differences in the data, Plot 3: 1995 - 1000/ha., 1996 - 250/ha. and Plot 8: 1995 - 2450/ha., 1996 - 500/ha. (Table 1). The average number of plants that flowered/hectare was: 16.5. The variation of the number of plants flowering by plot number and year is shown in Table 2. These data were averaged using the data from all nine plots collected during the two year study period. The information and analysis below go into comparisons between the grazed area and the non-grazed area.

Reproductive Data

The average number of fruits per plant was 430. The total potential fruits per plant (the number of fruits added to the total number of aborted fruits) was 2,241. The percent fruit set was 19.5% with a range from 0% to 54.2%.

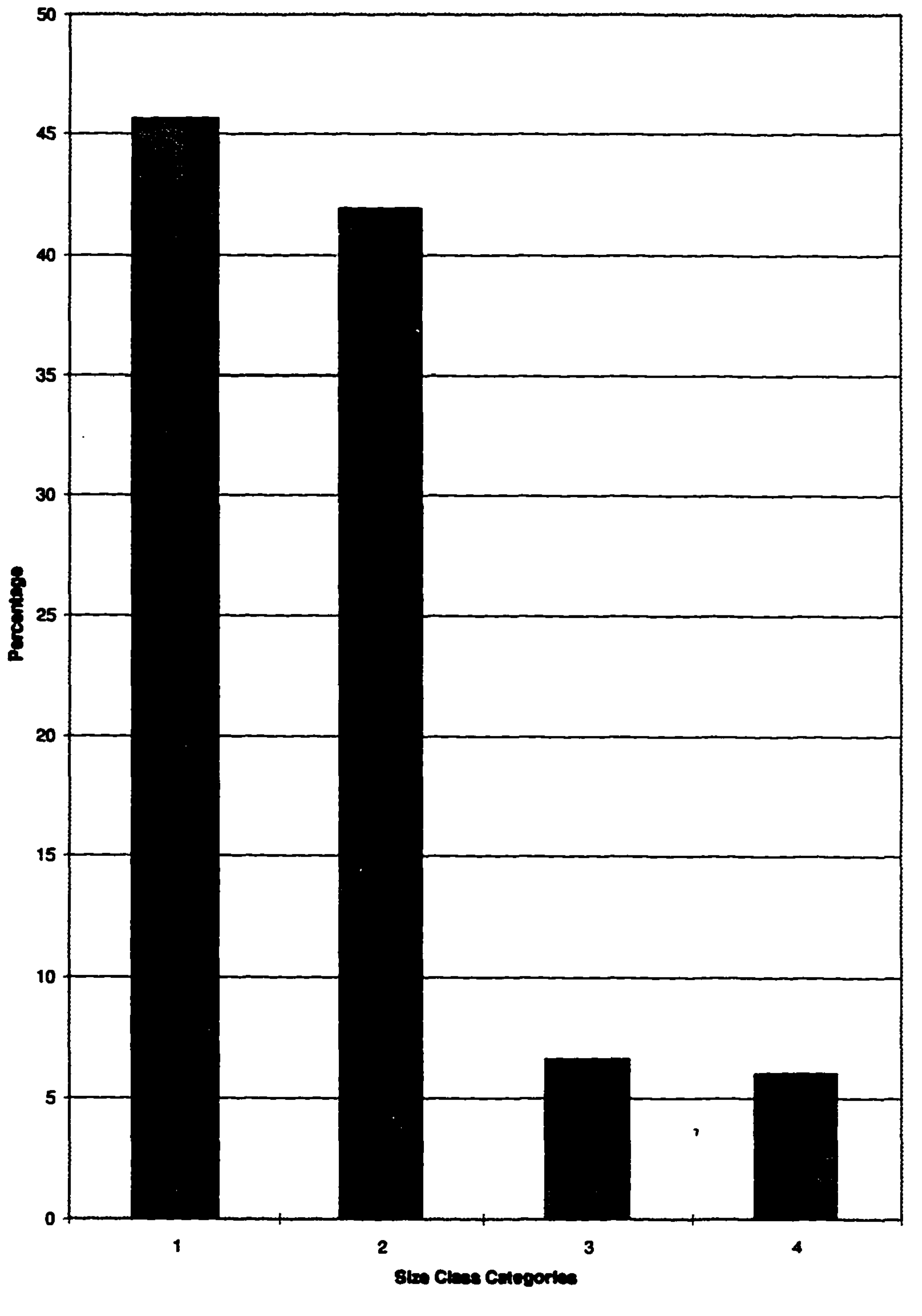


Figure 7. Distribution of individuals in the population by percentage that each size class represents. Size class 1 is the smallest.

Table 1. This table shows the range of values for the number of plant/size class/hectare, between plots and between years.

Plot ID	Year	Size Class 1	Size Class 2	Size Class 3	Size Class 4	Total
1	1995	3300	2950	400	250	6950
1	1996	2150	2500	400	400	5550
2	1995	2200	2950	350	150	5700
2	1996	2000	1950	350	300	4700
3	1995	1000	400	100	50	1550
3	1996	250	350	0	0	650
4	1995	2200	1950	200	100	4450
4	1996	3250	2100	300	100	5850
5	1995	1750	2150	250	200	4350
5	1996	850	1650	400	250	3150
6	1995	250	150	0	0	400
6	1996	450	300	100	100	950
7	1995	0	50	0	50	100
7	1996	50	0	0	50	100
8	1995	2450	850	150	50	3500
8	1996	500	550	150	200	1400
9	1995	700	650	100	150	1600
9	1996	400	350	200	150	1150

Table 2. This table shows the variation of the number of plants that flowered, between plots and years. Plots 1 - 5 and 10 and 11 are not grazed.

Plot ID	Year	# of Plants Flowered
1	1995	8
1	1996	3
2	1995	11
2	1996	6
3	1995	0
3	1996	1
4	1995	1
4	1996	3
5	1995	7
5	1996	4
6	1995	0
6	1996	0
7	1995	0
7	1996	1
8	1995	1
8	1996	1
9	1995	1
9	1996	1
10	1995	14
10	1996	7
11	1995	39
11	1996	9

Grazing Effects

There was no significance, within 95% confidence, for the size class distribution comparisons between plots that were exposed to grazing versus the plots that were not. A graphical comparison of the means of the two treatments is shown in Figure 8. Two sets were significant at the 75% level. Class 2 with an f-value of 3.32 with 5 and 2 degrees of freedom and class 4 with an f-value of 3.60 with 5 and 2 degrees of freedom.

There was no significant difference between the number of plants that flowered within grazed areas and within non-grazed areas (f-value of .076 with 5 and 2 degrees of freedom). The percent flowering stalks eaten had a significant difference between the grazed and non-grazed areas, within the 75% confidence level (Figure 9). No analysis showed significance to any higher level then 75%. This confidence level is rarely used, but, was presented here for purposes explained in the discussion.

Herbivory Effects

The average percentage of plants affected by stalk predation over the two year study was 75.2%. It was already stated above that there was a possible, yet weak, significance between the percentage of stalks eaten within grazing areas and outside grazing areas. In just comparing the percentage of flowering stalks eaten outside the grazing areas there was a possible difference between the individual plots with percentage of eaten stalks. The variation between individual plots and between years is shown in Table 3. This was significant within the 75% confidence level. The f-value =2.56 with 1 and 12 degrees of freedom. The mean percentage of eaten stalks in the non-grazed areas

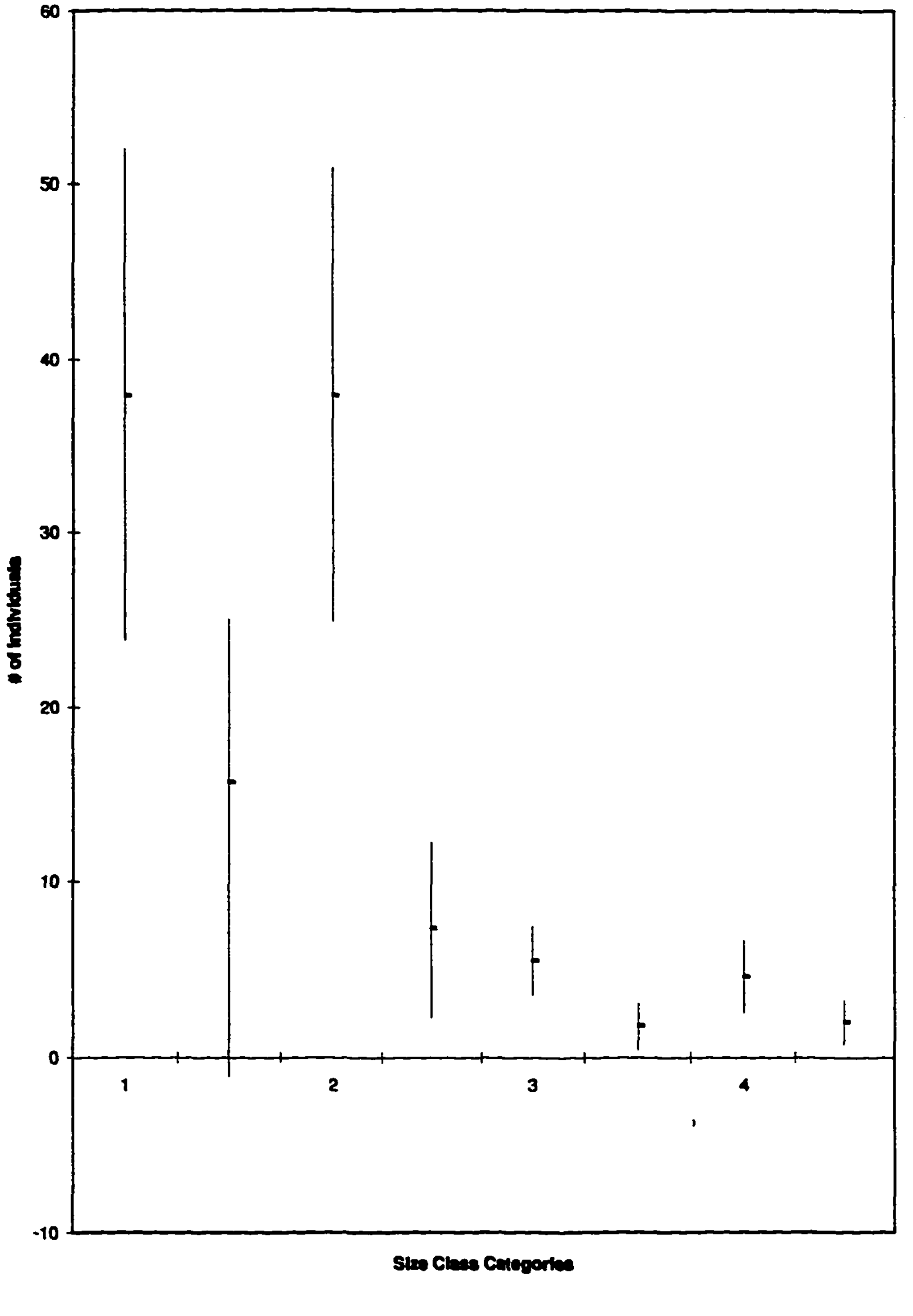


Figure 8. Recruitment value overlap, for grazed and non-grazed plots, with a 95% confidence interval. The first value is non-grazed and second is grazed.

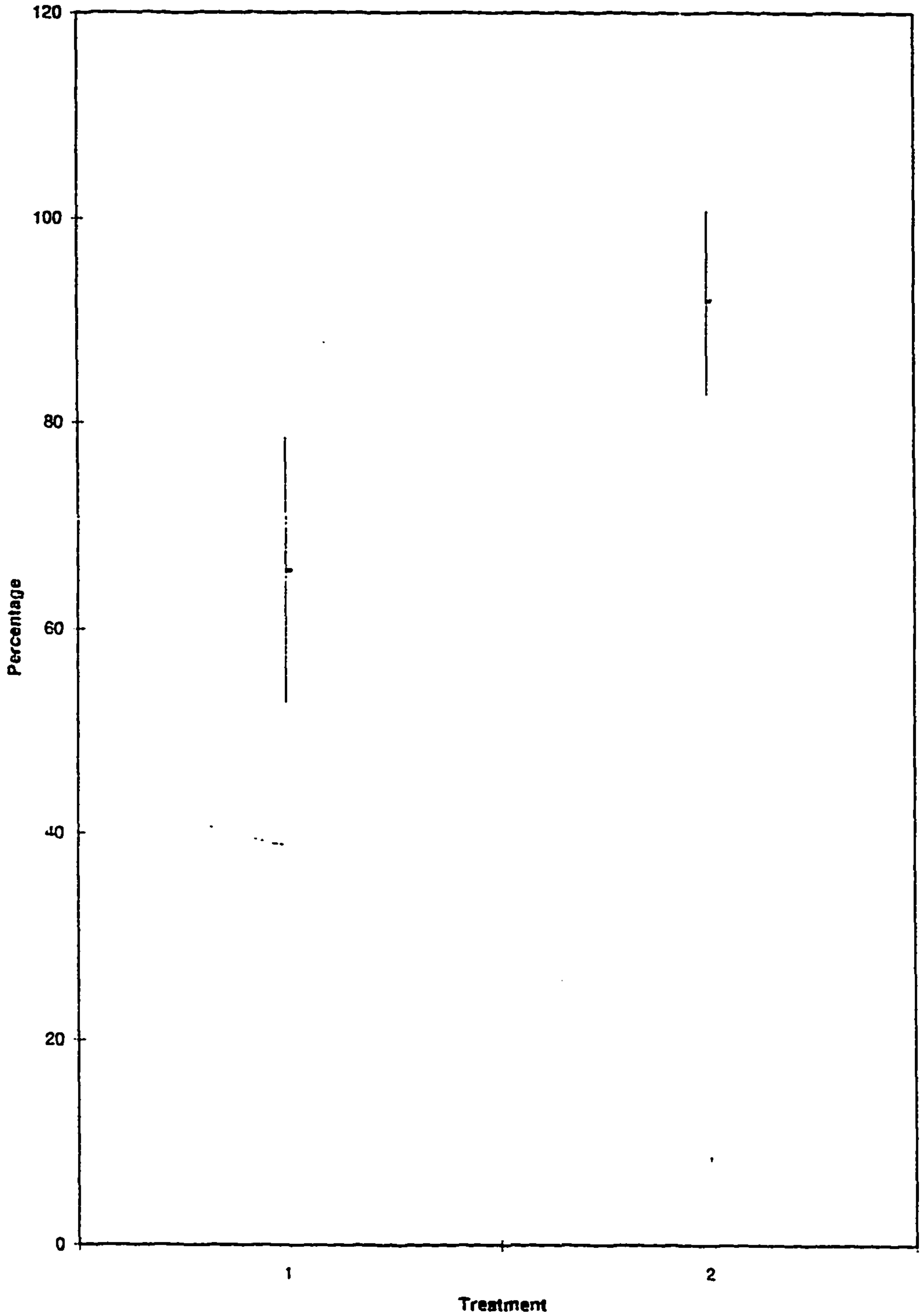


Figure 9. Variation between eaten stalks in grazed plots versus non-grazed plots. Number 1 is non-grazed and number 2 is grazed.

Table 3. Percentage of plants predated upon, 1995 - 1996. Plots 1 - 5 and 10 and 11 are not grazed.

Plot ID	Year	Percentage of Plants Eaten
1	1995	50
1	1996	69
2	1995	66
2	1996	76
3	1995	100
3	1996	92
4	1995	96
4	1996	84
5	1995	53
5	1996	60
6	1995	100
6	1996	100
7	1995	100
7	1996	66
8	1995	89
8	1996	92
9	1995	95
9	1996	90
10	1995	36
10	1996	53
11	1995	25
11	1996	59

was 65.7% with a variation of 25% to 100%. The grazed areas had a mean percentage of 91.8% with a variation of 67% to 100%. A graph showing the mean percentages with overlapping confidence intervals is shown in Figure 9.

Variations Within Treatments

The flowering data shows a weak significance (at the 75% confidence level) between the plots within the grazed treatment (f-value = 2.02 with 1 and 12 degrees of freedom). There was no significant difference between the plots within the control treatment.

The differences in size classes within treatments were mostly found not to be significant. One comparison that was significant was class 4 within the plots exposed to grazing (f-value was 11.45 with 1 and 6 degrees of freedom). Class 3 within the plots that were being exposed to grazing was significant at the 90% confidence level (f-value was 3.89 with 1 and 6 degrees of freedom).

GIS Database

The GIS data layers created for Coronado National Memorial were:

A boundary coverage which contains the outline of the CNM boundary shown in Figure 10.

A control points coverage containing three points used for geodetic control when using GPS to get plot locations present on the map that was used to digitize the boundary (Figure 11.)

Coronado National Memorial Boundary

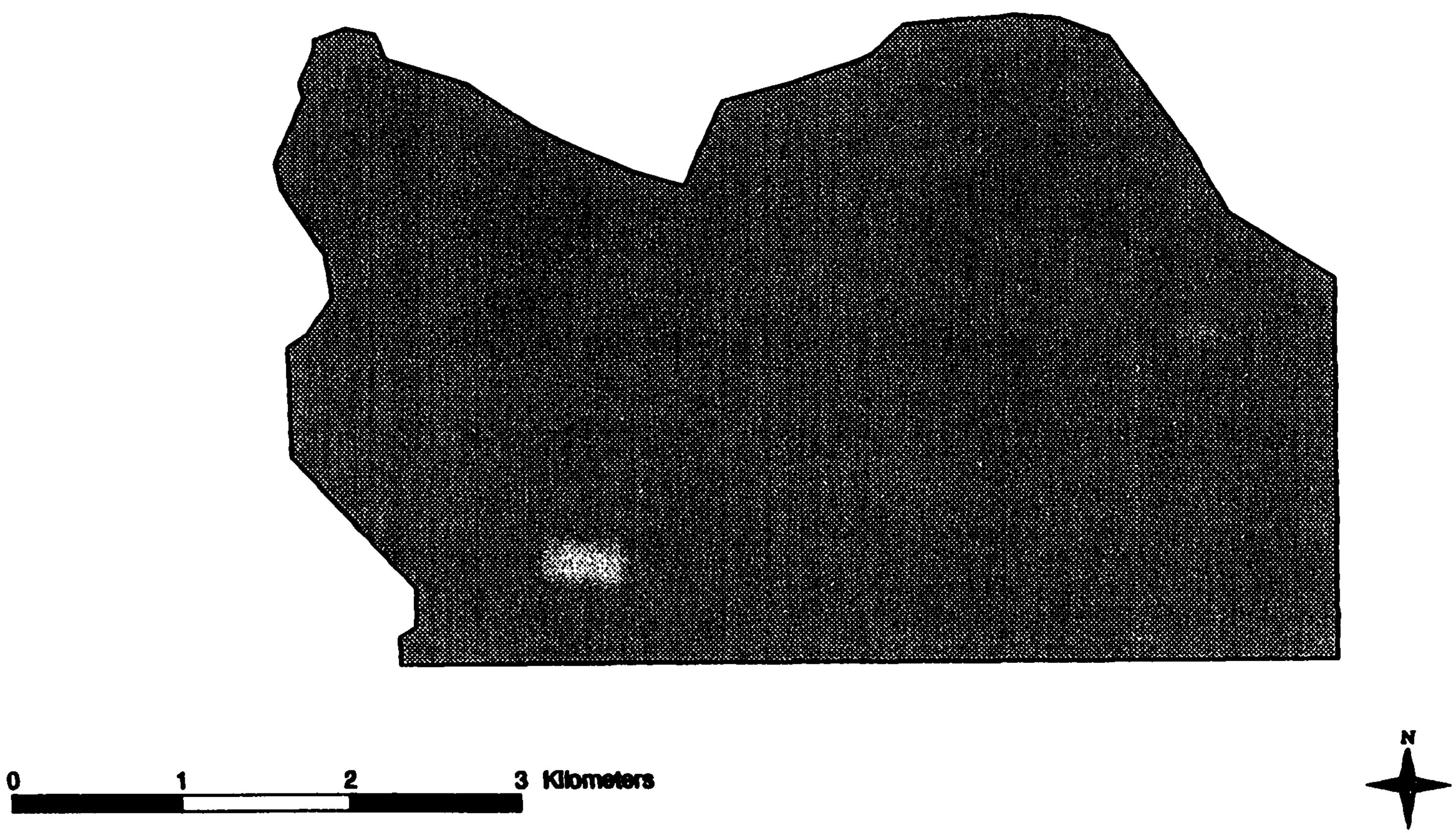


Figure 10. Boundary of Coronado National Memorial, that was digitiged from maps provided by the memorial. The projection is in UTM.

Control Points Used For GPS of Monitoring Plots.

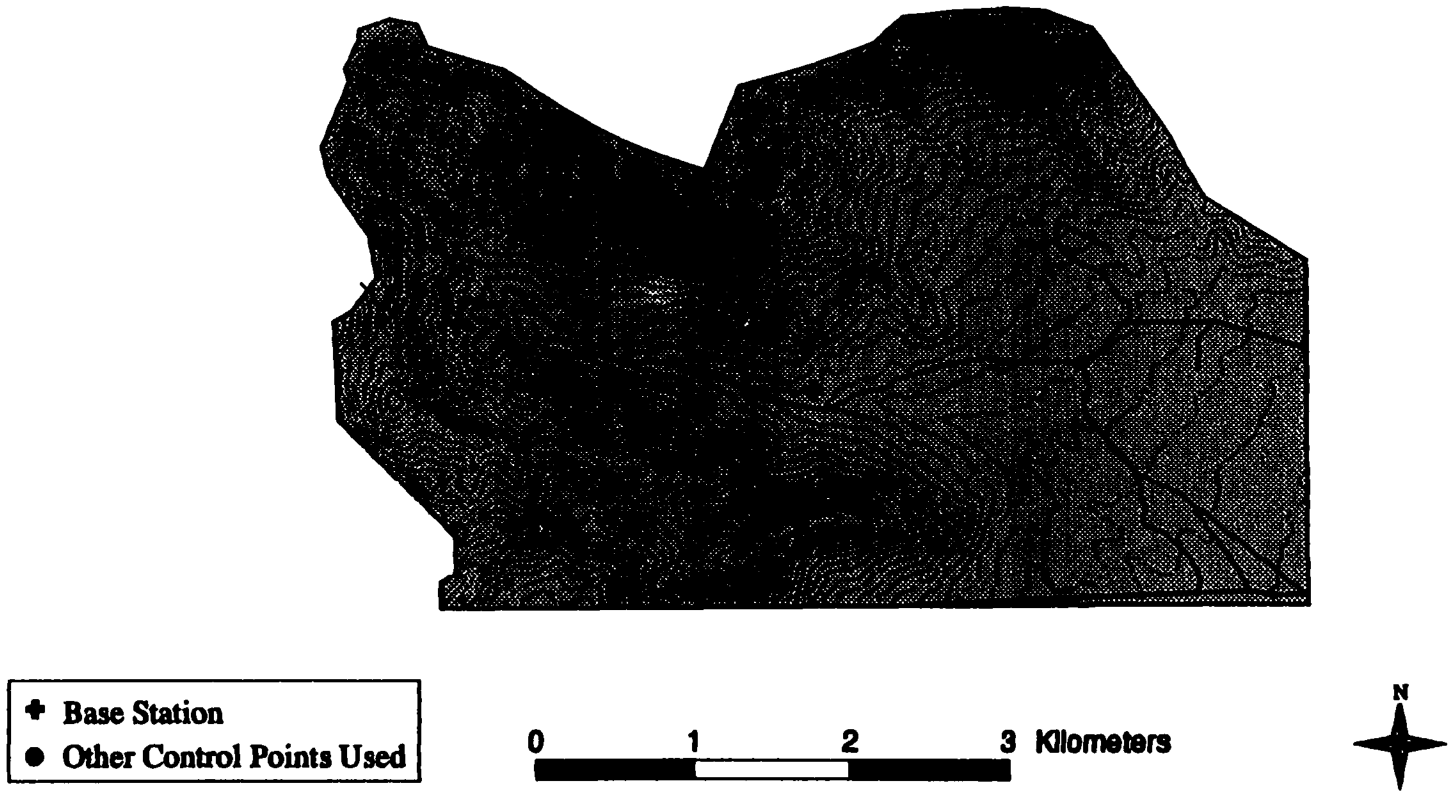


Figure 11. Control points used for GPS. The two represented by dots were already knowm locations, the cross was a location calculated using the other two points. The cross indicates the location of the base station, which was established on top of one of the houses there.

A roads coverage which contains the road that runs through the memorial from the eastern boundary up to Montezuma pass. It also contains some side roads that go to the border, lead into grazing allotments, and lead to the visitors center (Figure 12).

A contour coverage with contour lines in 10 meter intervals is shown in Figure 13. This coverage was created by extrapolating information from a digital elevation model.

A digital elevation model (DEM) is also part of the database. The DEM was converted and processed so that the elevation change could be visualized (Figure 14). The DEM is in a raster format, where each grid cell covers 30 meters of ground.

A vegetation coverage created from Ruffner and Johnson's vegetation survey of the memorial in 1991 is shown in Figure 15. The classifications are from Brown, Lowe and Pace (1979).

A vegetation coverage obtained from the Arizona GAP Project is shown in Figure 16. These vegetation classes are also based on BLP (1979).

A monitoring plot coverage has the nine monitoring plots that were used for this study (Figure 4). The plot locations were obtained with GPS. The coverage is a polygon coverage that has the plot ID number as one of the attributes in the coverage database table. This allows information from the database that was created to store the monitoring information to be related to the coverage data using the plot number ID.

A coverage of the transect locations was also created. The coordinates where the transects started were obtained through GPS and the transect lines were created

Roads Coverage of Coronado National Memorial

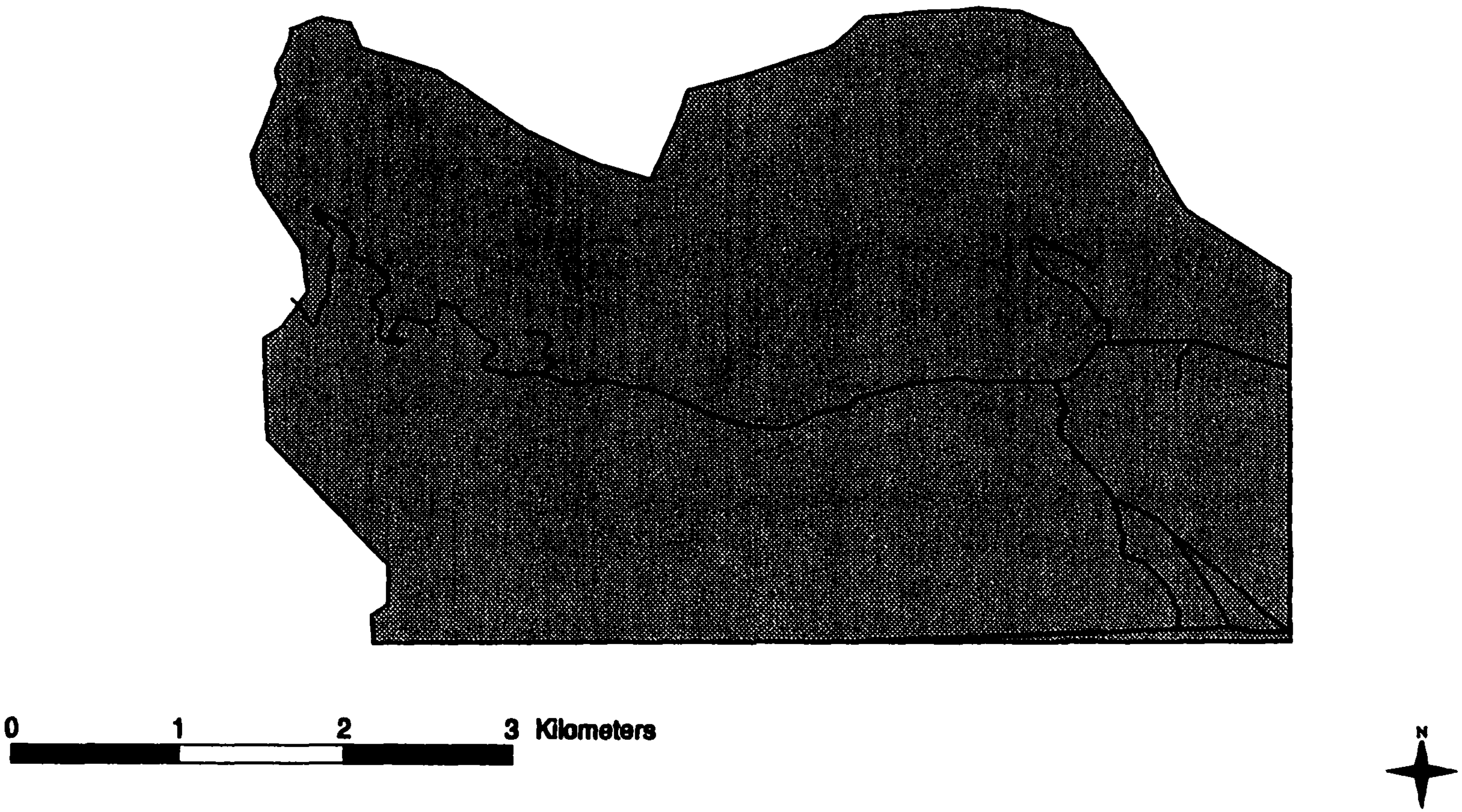


Figure 12. Roads civerage of Coronado National Memorial. The roads were obtained from TIGER data. The projection is UTM.

Hypsography of Coronado National Memorial

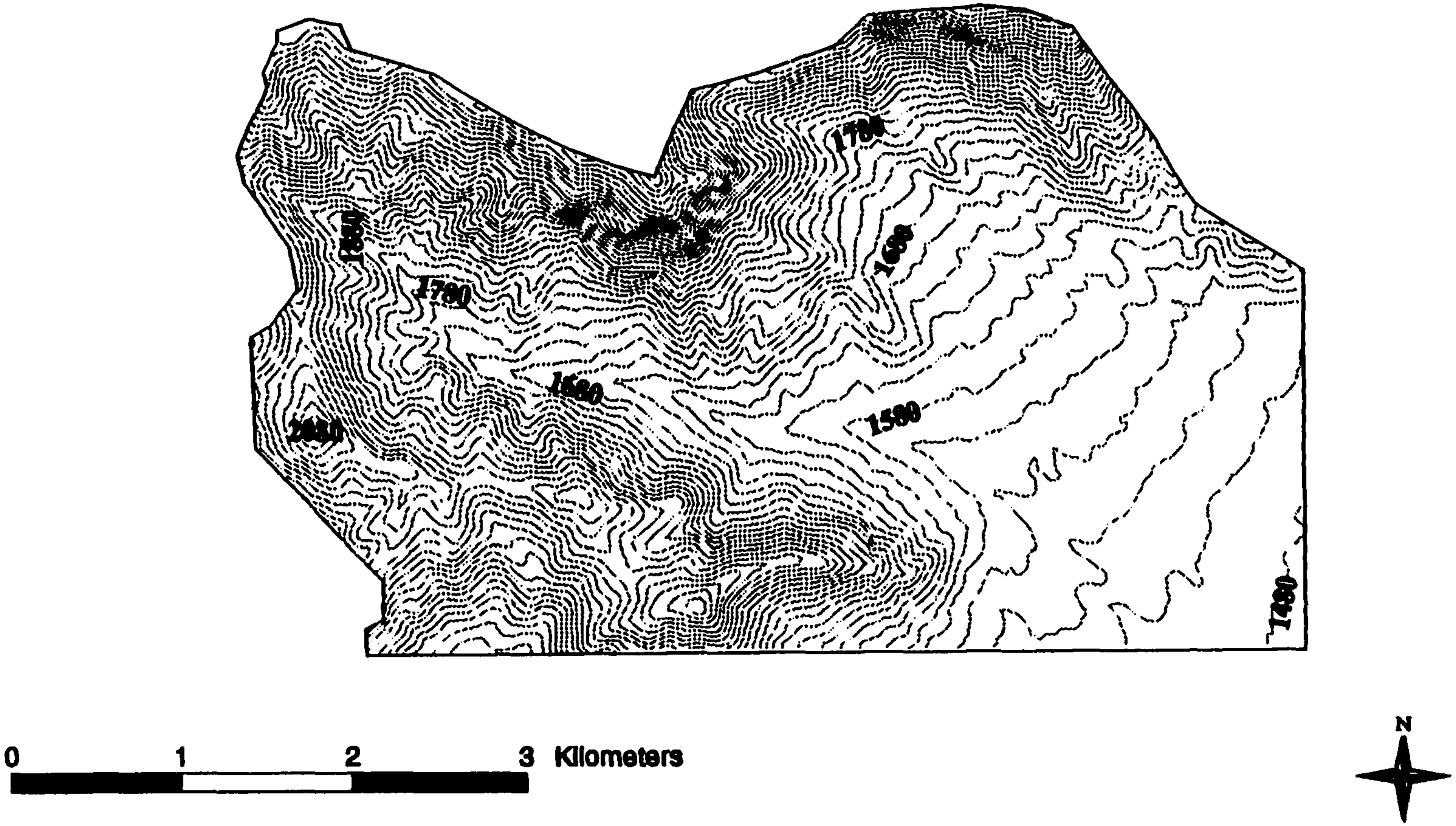


Figure 13. Contours derived from 30 meter Digfital Elevation Model (DEM) of Coronado National Memorial. The interval displayed between contours is 20 meters, however the coverage has data for contour lines every 10 meters. The projection is in UTM.

Hillshade Relief Map of Coronado National Memorial

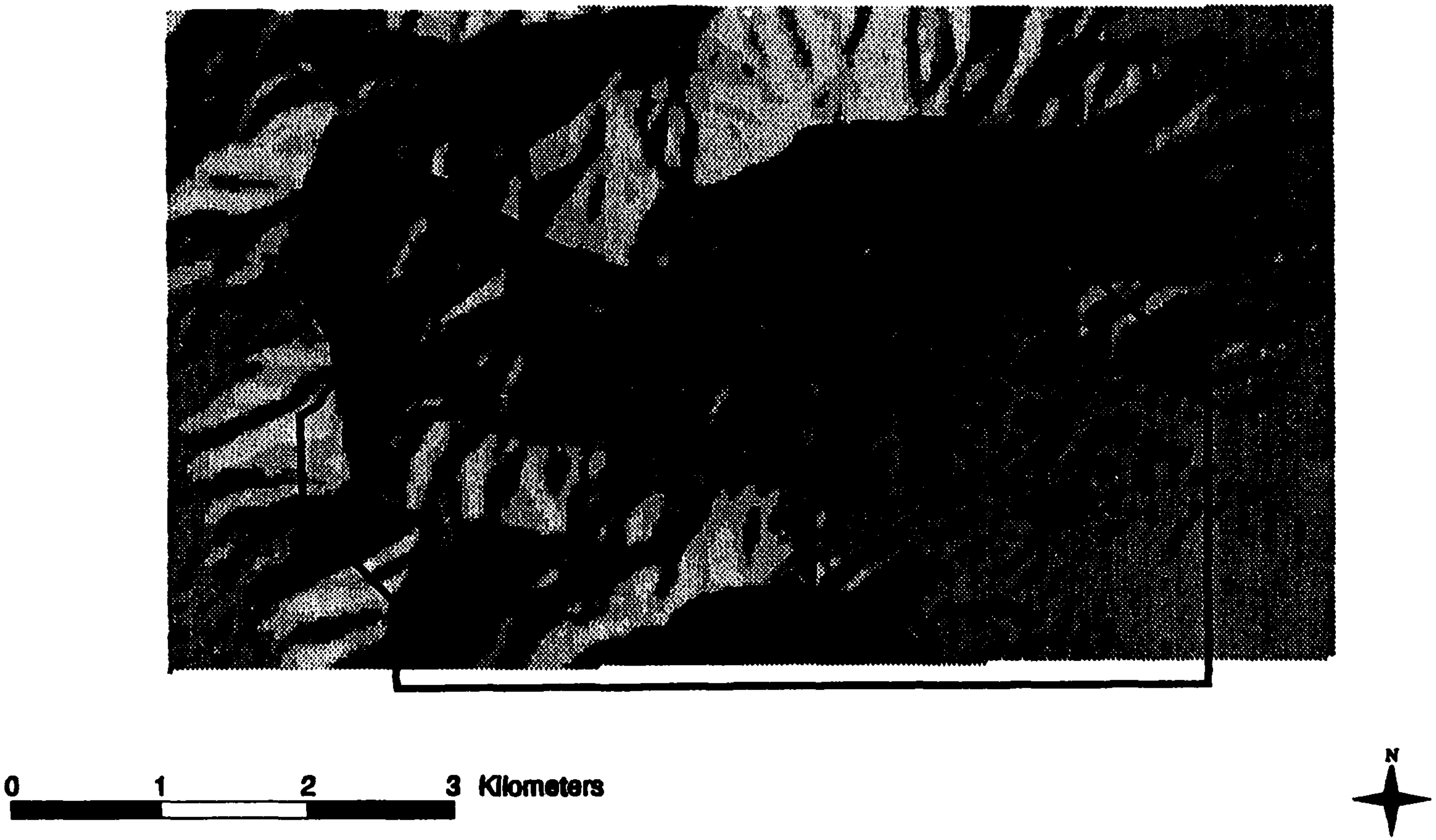


Figure 14. Hillshade from the 30 meter DEM of the areas around Coronado National Memorial. The black line represent the border of the memorial.

Vegetation Coverage of Coronado National Memorial

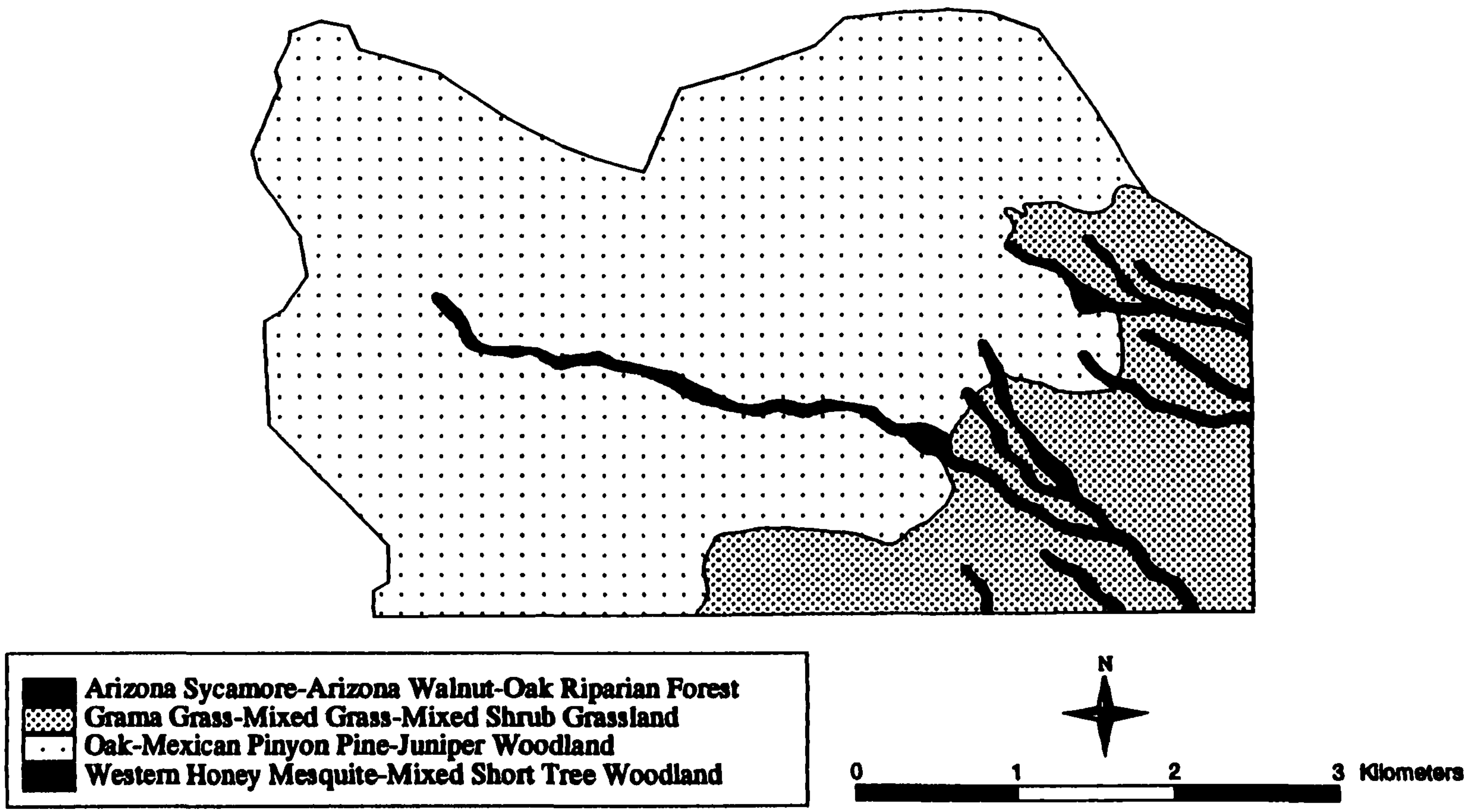


Figure 15. Vegetation coverage identified by Ruffner and Johnson (1991). The coverage was digitized from a map created from the vegetation study. The projection is in UTM.

GAP Vegetation Classifications Present in Coronado National Memorial

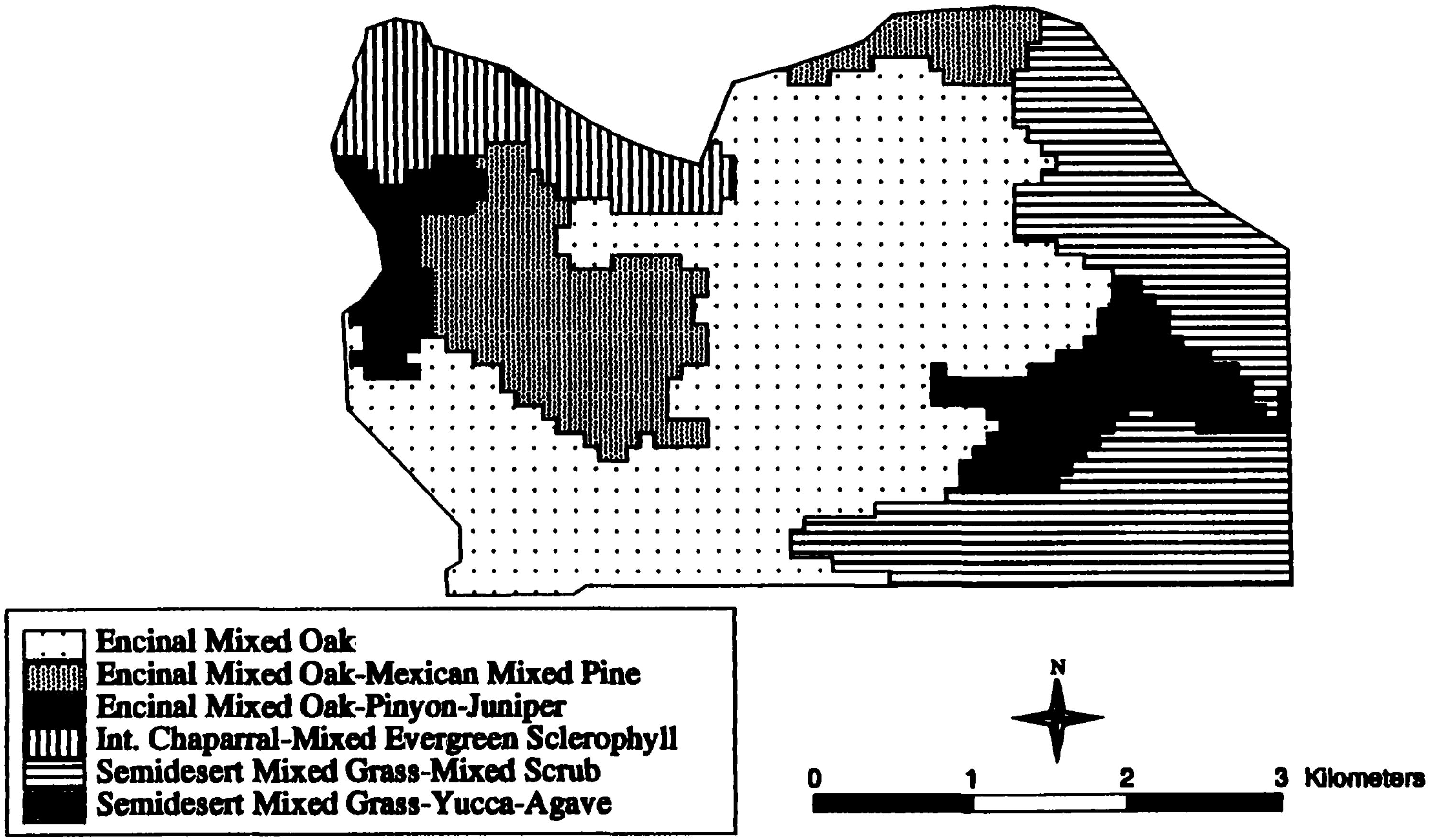


Figure 16. GAP Analysis vegetation map. It was clipped out from the state wide coverage of Arizona. The projection is in UTM.

through Coordinate Geometry (COGO) in ARC/INFO (Figure 17). All the coverages are in projection: UTM, units: meters, DATUM: NAD27.

A database was created to store information from the long-term monitoring program. This database stores information based on plot ID number. With the plot ID number the data stored in the database can be related to the location of the monitoring plots in the plot coverage. This is shown in Figure 18. The relationships between the tables within the database created are shown in Figure 19. The descriptions of the tables in the monitoring program database and the database tables associated with all of the GIS coverages are included in Appendix A.

Locations of Recruitment Survey Transects, at Coronado National Memorial

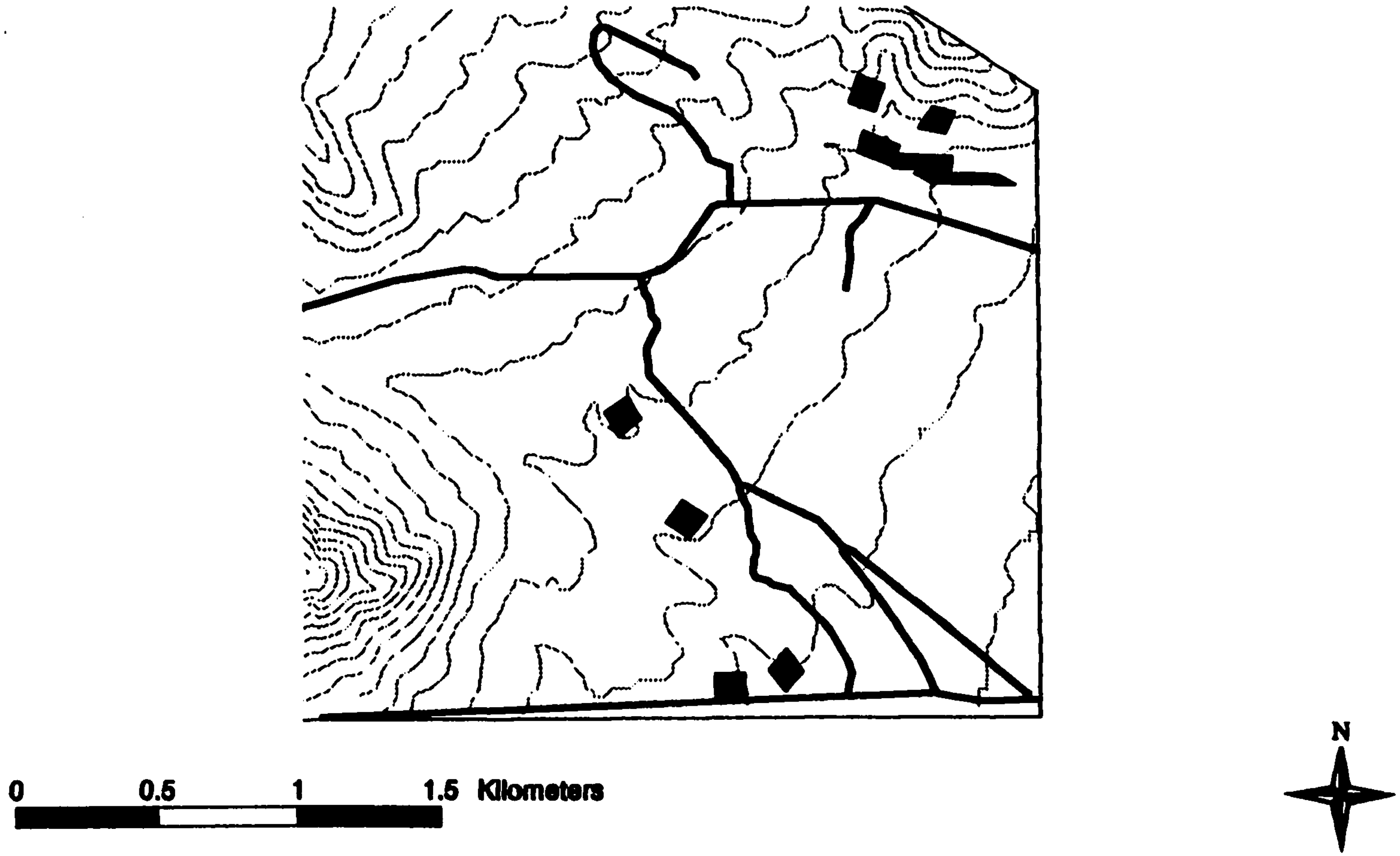


Figure 17. Transect locations used for the recruitment surveys, within the monitoring plots. This is a zoom in to the area where the plots are located. The map is projected in UTM.

Comparisen of the Number of Plants Per Hectare, Within Each Plot.

Plot ID	% Eaten	Total
9	95.2	1600
7	66.7	100
6	100.0	950
5	60.0	3150
4	84.2	5850
3	92.3	650
2	76.7	4700
1	70.0	5550
8	92.3	1400

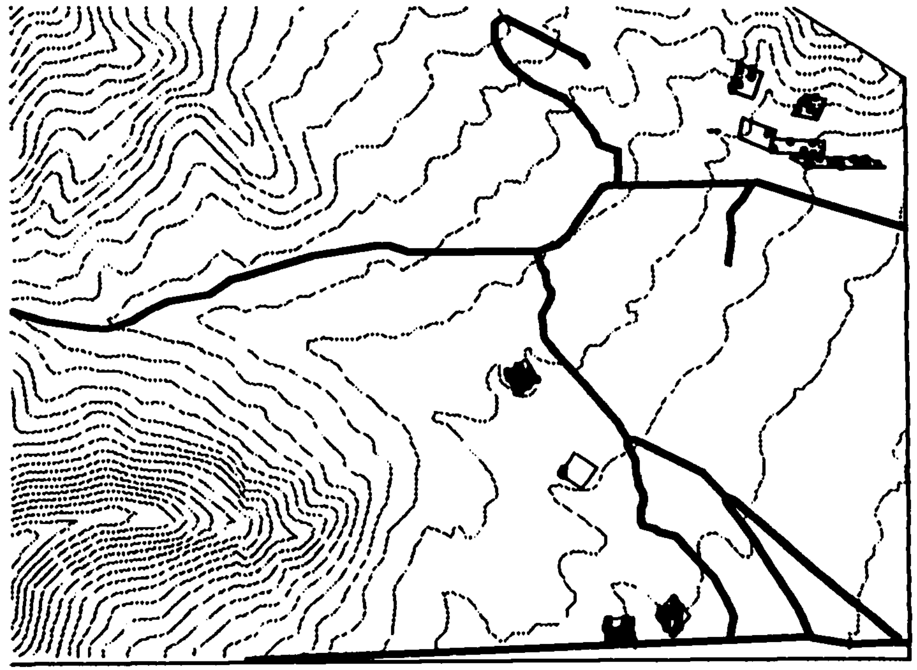


Figure 18. Data from the agave monitoring program present in the database was used to create this visual comparisen. Each dot within the plots represents 200 plants. The data was related via the plot id number. The table shows the plot id and other information obtained from the database (% stalks eaten, and total number of plants in each plot.).

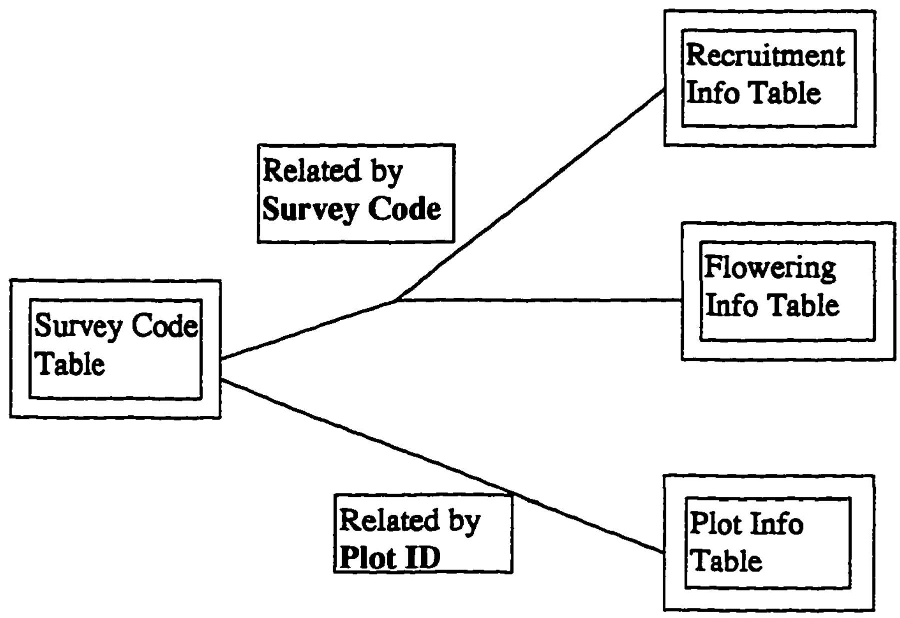


Figure 19. Relationships between tables present within the relational database setup for the monitoring program.

DISCUSSION

General Population Information

Size class distribution in the population shows a large number of plants present in the smallest size classes. There is a sharp decrease in numbers between class 2 and class 3 while there is little decrease in the number of individuals between class 3 and class 4. A graphical representation is shown in Figure 7. This demographic structure mimics a type II survivorship curve, where there is a high mortality in younger age classes with decreasing mortality till reproductive age. Howell (1995) found this same demographic structure present in the Palmer's agave population at Ft. Huachuca. The data collected is a snapshot in time. A cohort was not followed from germination till death. This means that each of the many cohorts represented in the data could have been exposed to various environmental factors that would affect how the populations looks. Ideally, one would collect data for the lifetime of a number of specific cohorts, to get a better understanding of the dynamics of the population. The high numbers of young plants is also an indication of high recruitment. The high numbers of young individuals could indicate an increase in the population. A population that is declining or unstable, would have lower numbers of younger individuals and a larger number of older individuals.

Related to population distribution, is patch dynamics. It was mentioned in the methods that Palmer's agave has a clumped distribution. The dynamics within various patches may vary from the population as a whole. Patch dynamics is a term that has generally been used for the description of populations that have been separated due to habitat fragmentation. The sub-populations (metapopulations) that exist in the patches will blink in and out of existence, while the population as a whole may be fairly stable. This term can also apply to species such as Palmer's agave which exist in patches throughout the landscape due to their reproductive biology. These individual patches may exhibit separate trends from the whole population.

Howell (1995) had observed that there seemed to be Palmer's agave patches that consisted of many of older, flowering age agaves, but where few young plants were present. There were also some patches with more young individuals present. The patches with many older plants and few young ones, could be senescing whereas the younger patches could be new patches that didn't exist 20 years ago. There could be some type of cycle that occurs within patches. Older ones die out, new ones emerge; like the metapopulations of fragmented populations. Howell (1995) mentioned this type of cycle, possibly occurring with the agave. This pattern has also been recognized in saguaros (*Carnegiea gigantea).* In a population study by Steenbergh and Lowe (1983) they found that the saguaro population at Saguaro National Park was predominately old individuals with little to no success for seedling establishment. In 1992 Turner reported that the population now was comprised of 76% young individuals, but they also found patches of saguaros that were still predominately older individuals. The research on saguaros has occurred since 1961 (Turner 1992). Long-term research is essential to understand if a pattern such as the one described is occurring or not. The scope of this research did not cover possible patch dynamics. The monitoring program that was set up at Coronado

National Memorial could produce information about the patch dynamics occurring at the memorial after 30 to 40 years of data collection. This concept is brought up for two reasons, first it shows why just a snapshot survey is not enough to understand population dynamics. Also, if these plants are affected by patches blinking in and out, it will be important to know what might affect the establishment of new patches and what might cause them to die out.

The recruitment data did show some isolated differences between 1995 and 1996. Are these differences a clue that the population is declining? The problem with looking at just two years of data is that there are so many possibilities as to why there is a difference. The data collected in 1996 was collected in July instead of August. By mid-August, Arizona is in the midst of its rainy season. In early to mid-July very little rain has fallen since the winter months. The seeds of agave may not germinate till the summer rains. This would mean that the first year of data collection, included all new plants added to the population. The data from 1996 would include all plants that survived the winter and summer drought, which would be a considerably smaller number.

Another possible reason for the change in plant numbers could be due to the drought conditions that were present in 1996. Very little rain fell over the winter rainy season, causing very dry conditions at the beginning of the summer. These conditions could have caused more plants to die and hindered germination. It is possible that there are large number of years where recruitment is very low, and then every few years there is a high germination and recruitment event. These events are what keep the population from disappearing during the years of low recruitment. Whatever the cause, it will take many more years of recruitment data collection to understand what is occurring.

The flowering information is hard to quantify without information about other populations or flowering data from this population collected in the past. Over a series of years of data collection, trends of flowering number/hectare may show things like how well recruitment was 20 or so years before and may be correlated with weather information. The average number of flowering individuals per hectare, for 1995 and 1996, by itself is not as useful as it will be in the future, as is the case with all these data. It is a baseline for where we started data collection and will be important in years to come for analysis.

Reproductive Data

The fruit set information for the memorial was similar to the fruit set information that Slauson had taken in other study areas. The percent fruit set for the memorial was 19.5 whereas in other study areas (Santa Rita and Mustang) the percentages were 16.9 and 21.4 respectively. These numbers are lower than what Howell found at Ft. Huachuca (averages ranged from 32% to 45.6% for various treatments). The treatment closest to the population at Coronado had a percentage of 32%. The surveys that Howell used to determine the fruit set were similar the Slauson's. Howell counted all fruits on five plants within each of 30 plots.

Comparing this work with that of Slauson the population at Coronado is healthy, in terms of reproduction. The samples taken for the survey may be biased though. The area that was sampled was in and near plot 2. Areas exposed to more severe stalk predation and grazing were not sampled. The information from Slauson only gives us one measurement of reproductive potential, but what if areas that have fewer flowering individuals tend to have larger fruit sets due to less competition? It is possible that the other areas on the memorial have lower production due to other factors such as soil type. There was a bit of variation of fruit set from Howell's report based on various elevations, burn history and soil type. There should be more areas sampled within the memorial.

There were no germination studies done with the seeds from Coronado. Very few have been done with Palmer's agave in general. Slauson mentioned that it is fairly easy to get an agave seed to germinate. Howell (1995) did some germination studies on Palmer's agave from Ft. Huachuca. She found that in a greenhouse situation germination was quite high, all the seeds needed was a steady supply of water.

Grazing Effects

The data show no strong significant differences between any of the size classes between grazed and non-grazed areas. The simplest conclusion would be that grazing does not affect agave. I think, however the answer is a bit more complicated. The data were only collected for two years, and there was a weak significance between size class 2. This is a complex system, with many factors acting on the organisms.

The areas that were used for plot locations have both been grazed in the past. Palmer's agave is a long-lived species. The type of management practices, weather and other environmental factors that were occurring 20 years ago had profound affects on the oldest age class present today. Howell (1995) saw that fires that occurred many years in the past were possibly affecting the dynamics of agave patches right now. This implies that to really survey the differences between grazed areas and non-grazed areas, the areas that were once grazed should have a substantial amount of time to recover before a comparison is made. The younger classes of plants could be showing a difference on the treatments, because grazing has not occurred there for four to five years, but this is dependent on what else is influencing the population. If there have been a few bad years for recruitment, there may not be any difference seen. In any case, a number of years of surveys are really needed to give any good quality hypothesis about what is occurring in the population.

Maybe, there is no difference in numbers that exist on grazed versus non-grazed plots. These plants have existed in this area for many years, with grazing occurring at the same time. This in itself could be proof that grazing is not affecting the plants. The agave could be resistant, up to a specific stocking rate. The level of resistance would be considered a threshold. The grazing could be occurring at an intensity that is below this threshold of impacts that the agave can withstand. This would mean that there would be no apparent influence by grazing, but grazing complicated with other environmental factors that negatively affect the plant could raise the level of impacts on the plant to above this threshold. Then environmental factors that normally would have little affect could potentially be devastating.

A study by Martinez-Morales and Meyer (1985) illustrates a possible threshold found for marguay verde (*Agave salmiana ssp. crassispina*). This species has been declining within it's range in Mexico. Martinez-Morales and Meyer (1985) decided that overuse was affecting it's ability to perpetuate itself. Grazing occurs within it's range. A microclimate with more permeable soil and protection from cattle trampling existed within patches that were already established. This allowed existing patches to continue, but new ones could not get established. In this case without any other use of the plant, the population could be fairly stable because there were strongholds where patches already existed, but harvesting of older plants for mescal, caused the threshold to be broken. Once older plants were harvested, younger plants were exposed to trampling, and soil was compacted. The patch was destroyed, and would not have a chance to reestablish with grazing occurring. This example shows that to an extent these plants can withstand some impacts, but within a certain threshold. It will be important to try to identify this threshold for future management.

Studies by Hodgeson and DeLamater (1988) and Martinez-Morales and Meyer (1985) both found a high percentage of stalks eaten by cattle. This study showed that not only did the areas that were grazed have a high percentage of flowering stalks eaten, but so did the non-grazed areas. There seemed to be an large variation between plots, which is discussed in the following section. As for the areas that were grazed, all the showed about the same level of grazing impact. One or two stalks survived to flower within a plot. The grazing data was similar to the other studies. Hodgeson and DeLamater (1988) and Martinez-Morales and Meyer (1985) studies did not compare their findings with areas not exposed to grazing. They also did not reveal what the stocking rate was at their study areas. This makes it hard to compare effects that were found with various stocking rates.

Although this study was not conclusive concerning grazing impacts, cattle at the memorial still may pose a threat to agave populations. The average percent of eaten flowering stalks in the grazed areas was 91.8%. The scarcity of flowering stalks that survive to seed may significantly hinder sexual reproduction. Howell (1995) found that Palmer's agave does asexually reproduce, possibly quite prolifically, but you still lose the genetic variation and adaptability that comes with sexual combinations. This may be a consideration in setting up a grazing management plan, although the difference between grazed and non-grazed areas was weak at best.

Another effect of cattle eating the flowering stalks of the agave could be on other herbivores. Deer and other wildlife may depend on the water and energy obtained by eating the flowering stalks. These stalks shoot up about a month before white-tailed deer young are born. This energy may be very important for pregnant deer. The pressure of both cattle and other herbivores could cause this resource to be diminished causing less available for native wildlife that could depend on it. With more impacts on the flowering stalks, then pollinators, such as the lesser-long nosed bat, have less resources available to them. Palmer's agave, like many of the agaves, offers a lot of resources to the communities that it occupies. So, any impact on it could greatly affect many other species.

Herbivory

This study only surveyed one type of herbivory that could happen to an agave. The flowering stalk predation is the most visible, and easy to survey for, without missing an individual. The herbivores present on the memorial that are potentially eating the stalks are white-tailed deer, cattle and possibly squirrels. Howell (1995) found that pronghorn (*Anteilocapra americana*) and mule deer (*Odocoileus hemeinnus*) also eat the stalks. These two herbivores do not occur on the memorial. Other herbivores will chew on the leaves or burrow underground and eat the center (or bole) of the plant. White-tailed deer were observed quite a bit around the area that agave patches were located. Unfortunately, no surveys were done to see how much predation was due to white-tailed deer as opposed to other herbivores. I do believe that on the plots not being grazed, white-tailed deer were a main predator. Two of the most heavily hit plots were outside of the cattle grazed areas. The percent eaten stalks ranged from 100% to 84%. Obviously, cattle were not contributing to the predation in these plots.

No significant difference between the grazed and non-grazed areas was found. The comparison of stalk predation within the non-grazed areas showed that there was some variation between individual plots (displayed in Table 3). This variation could be a function of location. Some plots were on open, exposed slopes where as others were more sheltered, being situated between or near draws. These data suggest that the areas along the draws got hit harder due to their closer proximity to cover. White-tailed deer are known to be skittish and inhabit the oak woodland and pinyon - juniper forests of this state. These areas offer more cover for this elusive species. The plots on the open grassland, generally seemed more productive but, were impacted less by the herbivores such as the white-tailed deer. I observed many white-tailed deer running along or into the draws in the memorial. The densely vegetated draws seem to be travel corridors for the deer. It would then make sense that the deer would tend to eat the flowering stalks of the plants closer to the draws (travel corridors) more than in areas where they were out in the open. If there were more than one large herbivore present, this pattern may not show up. Howell (1995) found that some areas on the open grassland were hit pretty hard, by pronghorn and mule deer. The pronghorn and mule deer are an open grassland species.

Other Considerations

The comparisons between plots within treatments revealed some significance when comparing the flowering data in the non-grazed areas. This shows that some environmental factor that could not be controlled varied between plots within a treatment. It is hard to determine what differed between the plots. So little is known about what affects these plants. It could be variation of soil types, a difference in slope or aspect, a difference in the exposure to grazing before cattle were taken off, or differing recovery rates from grazing. These factors are hard to control in field experiments, because we do not know about them. This does not mean that the results are completely invalid, but further experiments should be done with these variables kept constant.

There was variation between the plots within the grazed areas for size classes 3 and 4. Again, this means that some other factor was causing these plots to vary within a treatment. It is possible that it could have had something to do with the state of the plots from grazing impacts. Two of these plots were on land with little to no slope. These two plots seemed to have more cattle use. The earth was exposed in many areas and grass was eaten to the ground. The other two areas were up on slopes where cattle were known to go, but probably did not congregate in the concentrated numbers that occurred in the lower two plots. So, aside from any other possible difference in environmental factors the intensity of grazing may have varied enough to affect the results and cause the significant differences between class 3 and 4 within the grazed areas.

The varied intensity of grazing within treatments does pose a problem with the results. There are two ways to look at this dilemma. First, the variation could represent the variability that exists throughout the grazing allotment in which the plots are located. This would mean that the plot information averaged together results of the specific stocking rates of the allotment. The other way of dealing with the data is to decide that the variation does not give results that are accurate enough for the study. The grazing intensity is not represented correctly, so the study design should be altered to allow multiple plots representing various stocking rates, and then compare these plots with plots that are non-grazed. This could not be accomplished at Coronado National Memorial. The area was too small to find enough plots within these variations. Also, the scope of the project was not solely to look at grazing effects, but to get a better understanding of the population in general.

GIS Database Integration

The database created for the monitoring program was setup so that it could be related to the GIS information created. For this study the GIS data layers were used for reference, to indicate the plot locations for future researchers. In the future when more monitoring data is collected, the data in the database can be used as well as the GIS data for analysis. Possible analysis that could be done would be, prediction of where Palmer's agave might be found, or a comparison of results from monitoring surveys with the soil or vegetation types present in the monitoring plots.

CONCLUSIONS

The project's main goal was to determine the initial status of Palmer's agave, through setting up a monitoring program. The flowering data collected indicate that the population is producing a similar number of umbels to other populations in the state. The results from the recruitment data and size class distribution were similar to what Donna Howell found at Ft. Huachuca. There were many young plants present and fewer older plants. The data also show that the population seems to be stable or possibly increasing, due to the high number of young individuals present. The younger size classes had the highest mortality and that mortality decreased till flowering. It will be hard to conclude how healthy the actual status of the population till more seasons of data are collected. There is no previous study that indicates what a healthy population of agave is, so there can be no comparisons with the results of this research. Another objective of this study was to determine the extent of herbivore predation in Palmer's agave. Palmer's agave flowering stalks proved to be fairly important to the herbivores present in the plant's range. High predation occurred in all the plots, grazed and non-grazed. The final objective was to determine if grazing was negatively affecting Palmer's agave. There is no evidence that grazing is impacting the population, no significance between recruitment in the two treatments was found. It was also determined that other herbivores, such as deer can cause as much stalk predation as cattle.

Continued monitoring is encouraged. More information should be collected to determine the extent and nature of patch dynamics occurring. It will be important to understand for improved management in the future. Studies should be done to look at other effects on Palmer's agave. A study with more plots where some differ with soil type, some differ with slope and so on should be conducted. An expanded study such as this would have to be conducted beyond the borders of the memorial, due the small size of the memorial. There is little germination data. Further research could investigate a field experiment in which seeds are taken and put in an outdoor plot to determine germination in an uncontrolled environment.

Grazing effects at the memorial may be so subtle that it will take more than just a few years of monitoring to discover. Better information about how different intensities of grazing affect the species should be looked at. It seems that there is a need for that type of study, considering the number of papers written on grazing effects that do not even mention stocking rates. Fruit set data should be taken in each of the plots especially the grazed areas, so a better average can be found. This could reveal other possible effects of grazing on the species.

Many species in the*Agave* genus are becoming threatened, due to habitat destruction and overuse of the land (Reichenbacher 1985). Data about population dynamics may help us understand how to reduce and stop their decline. The*Agave* genus is present throughout Southwestern United States, Mexico, and Central America. This makes any type of research and conservation a little more difficult. Agave do not adhere to political boundaries. Cooperation between countries will be a step towards helping scientists understand these border species, such as Palmer's agave.

The monitoring program was set up for the staff of Coronado National Memorial to obtain data about Palmer's agave for 20 to 50 years. With more data, more sensitive comparisons can be made, leading to more solid conclusions. The importance of this plant to the communities that it occupies, make it an important plant to study and understand for conservation and management of the systems where it is found. Palmer's agave is an important food source for the lesser long-nosed bat, a federally listed endangered species. It will be important to know what is affecting the plant populations that are important to an endangered species. Without further study it will be difficult to predict how much disturbance these populations can endure.

APPENDIX A

Definitions of the related database tables for the coverages created of Coronado National Memorial.

Definition for boundary.pat (database table associated with the boundary coverage)

Field Name	Width	Type	# Decimals	Description
AREA	8	floating point	5	The area of the polygon being described.
PERIMETER	8	floating point	5	The perimeter of the polygon being described.
BOUNDARY#	4	binary	0	The internal ID number for the polygon being described.
BOUNDARY-ID	4	binary	0	The user defined ID number for the polygon being described.

Definition for control.pat (database table associated with the control points coverage).

Field Name	Width	Type	# Decimals	Description
AREA	8	floating point	5	The area of the point being described. This will always be zero.
PERIMETER	8	floating point	5	The perimeter of the polygon being described. This will always be zero.
CONTROL#	4	binary	0	The internal ID number for the point being described.
CONTROL-ID	4	binary	0	The user defined ID number for the point being described.
CPNAME	9	character	0	The name of the control point given by the surveyor.

Definition for roads.aat (database table associated with the roads coverage).

Field Name	Width	Type	# Decimals	Description
FNODE#	4	binary	0	Point of origin of the line, used to establish topology.
TNODE#	4	binary	0	Point of termination of the line, used to establish topology.
LPOLY#	4	binary	0	Polygon on the left of the line, used to establish topology.
RPOLY#	4	binary	0	Polygon on the right of the line, used to establish topology.
LENGTH	8	floating point	5	Length of the line.
ROADS#	4	binary	0	The internal ID number for the line being described.
ROADS-ID	4	binary	0	The user defined ID number for the line being described.
FNAME	30	character	0	The name of the road the line represents.

Definition for contours.aat (database table associated with the contours coverage).

Field Name	Width	Type	# Decimals	Description
FNODE#	4	binary	0	Point of origin of the line, used to establish topology.
TNODE#	4	binary	0	Point of termination of the line, used to establish topology.
LPOLY#	4	binary	0	Polygon on the left of the line, used to establish topology.
RPOLY#	4	binary	0	Polygon on the right of the line, used to establish topology.
LENGTH	8	floating point	5	Length of the line.
CONTOURS#	4	binary	0	The internal ID number for the line being described.
CONTOURS-ID	4	binary	0	The user defined ID number for the line being described.
CONTOUR	4	floating point	3	The elevation in meters that is represented by the specific contour line.

Definition for cnmveg.pat (database table associated with the vegetation coverage from Ruffner and Johnson's data (1991)).

Field Name	Width	Type	# Decimals	Description
AREA	8	floating point	5	The area of the polygon being described.
PERIMETER	8	floating point	5	The perimeter of the polygon being described.
CNMVEG#	4	binary	0	The internal ID number for the polygon being described.
CNMVEG-ID	4	binary	0	The user defined ID number for the polygon being described.
VEGCODE	8	floating point	3	The vegetation code designated by Brown, Lowe, and Pace (1979).
VEGDESC	60	character	0	The description of the vegetation association described by Ruffner and Johnson (1991).

Definition for cnmgap.pat (database table associated with the GAP vegetation coverage).

Field Name	Width	Type	# Decimals	Description
AREA	8	floating point	5	The area of the polygon being described.
PERIMETER	8	floating point	5	The perimeter of the polygon being described.
CNMGAP#	4	binary	0	The internal ID number for the polygon being described.
CNMVEG-ID	4	binary	0	The user defined ID number for the polygon being described.
V	3	number	0	The vegetation code used by GAP.
VDESC	75	character	0	The description of the vegetation identified for GAP.
VI	3	integer	0	The vegetation code used by GAP.

Definition for plots.pat (database table associated with the monitoring plot coverage).

Field Name	Width	Type	# Decimals	Description
AREA	8	floating point	5	The area of the polygon being described.
PERIMETER	8	floating point	5	The perimeter of the polygon being described.
PLOTS#	4	binary	0	The internal ID number for the polygon being described.
PLOTS-ID	4	binary	0	Each polygon is a monitoring plot, and this is the field that has the plot ID number.

Definition for transects.aat (database table associated with the transects coverage).

Field Name	Width	Type	# Decimals	Description
FNODE#	4	binary	0	Point of origin of the line, used to establish topology.
TNODE#	4	binary	0	Point of termination of the line, used to establish topology.
LPOLY#	4	binary	0	Polygon on the left of the line, used to establish topology.
RPOLY#	4	binary	0	Polygon on the right of the line, used to establish topology.
LENGTH	8	floating point	5	Length of the line.
TRANSECTS#	4	binary	0	The internal ID number for the line being described.
TRANSECTS-ID	4	binary	0	The user defined ID number for the line being described.
TRANSCODE	5	character	0	The code that describes whether the transect is the northern or southern transect, which plot it is in and for plot 5 whether it is transect number 1 or 2.

The following table definitions are from tables within the monitoring program database for Coronado National Memorial.

Definition of the Survey Code Table.

Field Name	Width	Type	# Decimals	Description
SURVEY CODE	50	character	0	A unique ID number, used for a relation key between database tables, it consists of the year of the survey and the plot ID number.
PLOT ID	ND	integer	0	The ID number of the monitoring plot being described.
YEAR	ND	integer	0	The year of the survey described in the survey code.

Definition of the Plot Info Table

Field Name	Width	Type	# Decimals	Description
PLOT ID	ND	integer	0	The ID number of the monitoring plot being described.
YEAR ESTABLISHED	ND	integer	0	The year the plot was created.
GRAZED	ND	Boolean	0	Whether the plot has been grazed or not, a yes indicates that the plot is in a grazing area.

Definition of the Flowering Info Table

Field Name	Width	Type	# Decimals	Description
SURVEY CODE	50	character	0	A unique ID number, used for a relation key between database tables, it consists of the year of the survey and the plot ID number.
TOTAL PLANTS FLOWERED	ND	integer	0	The total number of plants that attempted to flower within a plot.
# PLANTS EATEN	ND	integer	0	The number of plants that had flowering stalks chewed off within a plot.
# PLANTS FLOWERED	ND	integer	0	The number of plants that flowered without being eaten.

Definition of the Recruitment Info Table

Field Name	Width	Type	# Decimals	Description
SURVEY CODE	50	character	0	A unique ID number, used for a relation key between database tables, it consists of the year of the survey and the plot ID number.
CLASS 1	ND	integer	0	The number of plants counted within the transects set up in a plot that are size class 1 (the smallest size class).
CLASS 2	ND	integer	0	The number of plants counted within the transects set up in a plot that are size class 2.
CLASS 3	ND	integer	0	The number of plants counted within the transects set up in a plot that are size class 3.
CLASS 4	ND	integer	0	The number of plants counted within the transects set up in a plot that are size class 4.
FLOWERING	ND	integer	0	The number of plants counted within the transects set up in a plot that were flowering
TOTAL	ND	integer	0	The total number of plants counted within the transects set up in a plot.

LITERATURE CITED

Breitung, A.J. 1968. The agaves. Cactus and Succulent J. 31:44-46.

Brown, D.E., C.H. Lowe, and C.P. Pace. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. Ariz-Nev. Acad. Sci. 14: 1-16.

Burgess, T.L. 1985. Agave adaptation to aridity. Desert Plants 7:39-50.

Freeman, C.E. 1975. Germination responses of a New Mexico population of parry agave (*Agave parryi* Engelm. var. *parryi*) to constant temperature, water stress and pH. Southwest Nat. 22:157-168.

Gentry, H.S. 1972. The agave family in Sonora. Agric. Handb. No.399 U.S. Dept. Agric. 195pp.

Gentry, H.S. 1982. Agaves of continental North America. Univ. of Arizona Press Tucson, AZ. 670pp.

Hodgeson, W. and R. DeLamater. 1988. *Agave arizonica*: summary of status and report on recent studies. Unplublished.

Howell, D.J. 1978. Flock foraging in nectar-feeding bats: advantages to the bats and the host plants. Amer. Nat. 114:23-49.

_____. 1995. *Agave palmeri* on Ft. Huachuca; five years of research on natural history and response to fire. Summited to Ft. Huachuca Wildlife Office, Sierra Vista, Arizona. Contract # DAEA 1890C0079.

_____, D.J. and B.S. Roth. 1981. Sexual reproduction in agaves: the benefits of bats; the cost of semelparous advertising. Ecology 62:1-7.

Martinez-Morales, R. and S.E. Meyer. 1985. A demographic study of marguey verde (*Agave salmiana ssp. crassispina*) under conditions of intense utilization. Desert Plants 7:61-64.

McDaniel, R.G. 1985. Field evaluation of agave in Arizona. Desert Plants 7:57-60.

Nobel, P.S. 1984. Productivity of *Agave deserti*: measurement by dry weight and monthly prediction using physiological responses to environmental parameters. Oecologia 64:1-7.

Nobel, P.S. 1985. Water relations and carbon dioxide uptake of *Agave deserti*-special adaptations to desert climates. Desert Plants 7:51-56.

Nobel, P.S. 1988. Environmental biology of agaves and cacti. Cambridge Univ. Press, Cambridge. 253pp.

Nobel, P.S. and R.S. McDaniel. 1984. Low temperature tolerance, nocturnal acid accumulation and biomass increase for seven species of Agave. J. Arid Environ.

Ogden, P.R. 1995. Coronado National Memorial inventory and grazing management alternatives for Joe's Spring and Montezuma grazing allotments. Report to Superintendent, Coronado National Memorial.

Reichenbacher, F.W. 1985, Conservation of Southwestern Agaves. Desert Plants 7:103-106.

Ruffner, G.A. and R.A. Johnson. 1991. Plant ecology and vegetation mapping at Coronado National Memorial, Cochise County, Arizona. NPSCPSU, Univ. of AZ. Tech. Rep. No. 41.

Schaffer, W.M. and M.V. Schaffer. 1977. The reproductive biology of Agaveceae: I. Pollen and nectar production in four Arizona agaves. Southwest Nat. 22:157-168.

Slauson, L. 1996. A morphometric and pollination ecology study of *Agave chrysantha* (Peebles) and *Agave palmeri* (Engelm) (Agaveceae). Ph.D. Thesis. Arizona State University, Tempe, Arizona, 239 pp.

Steenbergh, W.F. and C.H. Lowe. 1983. Ecology of the saguaro: III. Growth and demography. Natl. Park Serv. Monogr. Ser. 17. 228pp.

Tello-Balderas, J.J. and E. Garcia-Moya. 1985. The mezcal industry in the Altipalana Potasino-Zactecano of North-Central Mexico. Desert Plants 7:81-87.

Turner, R.M. 1992. Long-term saguaro population Studies at Saguaro National Monument. Proceedings of the Symposium on Research in Saguaro National Monument. 23-24 January 1991. Tucson, Arizona. Pages 3-11.

Waring, G.L. and R.L. Smith. 1987. Patterns of faunal succession in *Agave palmeri*. Southwest. Natur. 32:489-497.