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Habitat Characteristics That Influence Maritime Pocket Gopher Densities

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ABSTRACT

The Maritime pocket gopher (*Geomys personatus maritimus*) is a subspecies of Texas pocket gopher endemic to the Flour Bluff area of coastal southern Texas. Little is known about the habitat and nutritional requirements of this subspecies. The amount and quality of habitat necessary to sustain Maritime pocket gophers has not been studied. Our objectives were to assess the habitat, vegetation, and nutritional parameters available to Maritime pocket gophers at four different levels of gopher mound density. We chose study sites with zero, low (25-50 mounds/ha), intermediate (75-150 mounds/ha), and high (>200 mounds/ha) gopher mound densities. Vegetation and soil samples were collected using 0.25 m^2 quadrats; vegetation was divided into above- and below-ground biomass for analysis. Maritime pocket gophers avoided areas of clay soils with high levels of calcium, magnesium, sulfur, and sodium compounds. A direct relationship existed between gopher activity within an area and vegetation biomass. However, nutritional quality of an area did not appear to be a determining factor for the presence of Maritime pocket gophers.

KEY WORDS: Population density, *Geomys personatus maritimus*, habitat selection, Maritime pocket gopher, preference

INTRODUCTION

The Maritime pocket gopher (MPG, *Geomys personatus maritimus*) is endemic to the coastal areas of Kleberg and Nueces counties of southern Texas, between Baffin Bay and Flour Bluff (Williams and Genoways 1981). Historically, this subspecies of pocket gopher was found on native prairies, but urbanization and agricultural practices have fragmented much of the coastal prairies. There is a dearth of published data on MPG, but few studies that have mentioned MPG focus on general morphology, distribution (Williams and Genoways 1981), and habitat (Williams 1982).

The MPG prefers deep sandy soils (Williams 1982) and avoids rocky, silt loam or clay soils due to the difficulty in excavation (Davis 1940; Kennerly 1958). Pocket gopher diet consists mainly of vegetation and includes grass species in the genera

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Paspalum, *Cynodon*, and *Cenchrus* and forb species in *Helianthus* (Davis and Schmidly 1994). It is thought that MPG has similar habitat preferences as the other six subspecies of the Texas pocket gopher, but no habitat preference studies with MPG have been conducted to confirm this.

Potential threats of habitat degradation, which converts native prairie into shrub land, and habitat fragmentation, which isolates populations of MPG and inhibits dispersal (Cortez 2007), place MPG in jeopardy for continued existence. Due to their restricted distribution and aforementioned threats, U.S. Fish & Wildlife Service has labeled the MPG as a species of concern (SOC) and has considered recommending it for federal listing status (Hafner 2000). Because the majority of the population of MPG occurs on Naval Air Station-Corpus Christi (NAS-CC), a U. S. Navy property, management by the Navy plays a vital role in the conservation of this subspecies. Therefore, determining the habitat characteristics that effect MPG densities will aid in creating a sound habitat management plan for this subspecies. The primary objective of this study was to determine habitat characteristics of soil, plant species composition, and vegetative nutrients that affect MPG density.

STUDY AREA

This study was conducted on NAS-CC in the Flour Bluff region, which is 16.1 kilometers southeast of Corpus Christi, in Nueces County, Texas, USA (27°41'33.47"N, 97°17'28.36"W). Flour Bluff is surrounded by Corpus Christi Bay to the north, Oso Bay to the west, and the Laguna Madre to the east, and lies in the Gulf Prairies and Marshes eco-region. Home to a U.S. Coast Guard base, an Army Depot, and a U. S. Navy base, NAS-CC is approximately 1,049 ha. The landscape of NAS-CC is urbanized with grassland and scrubland habitat fragmented by airfields, taxiways, and roadways.

Two soil types occur at NAS-CC, Galveston (Mixed, hyperthermic Typic Udipsamments) and Mustang fine (Siliceous, hyperthermic Typic Psammaquents) sand and dredge spoils (Fine-loamy, mixed, superactive, frigid Typic Haploxerolls) (Natural Resources Conservation Service (NRCS) 1960). The percentage of Galveston and Mustang fine sand and clay loam on NAS-CC is 80% and 20%, respectively.

The vegetation on NAS-CC is predominantly coastal, mid-grass prairie grasslands and scrub-dominated, mixed grassland communities. Both communities occur on Galveston and Mustang fine sand and clay loam. Grass species include sandbur (*Cenchrus spinifex*), gulf dune paspalum (*Paspalum monostachyum*), and red lovegrass (*Eragrostis secundiflora* subsp. *oxylepis*). Forbs include cardinal feather (*Acalypha radians*), frog fruit (*Phyla strigulosa*) and scarlet pea (*Indigofera miniata*). Additionally, there are three non-native grasses present: Bermuda grass (*Cynodon dactylon*), St. Augustine grass (*Stenotaphrum secundatum*), and guinea grass (*Panicum maximum* Jacq.).

MATERIALS AND METHODS

Gopher Assessment. Relative abundance of MPG was surveyed using strip line transect sampling. A strip line transect map was created using a 2004 National Agricultural Imagery Program (NAIP) aerial photograph of the study site. With ArcGIS 9.1, a 3-

hectare grid matrix was laid over the aerial photograph and each 3-ha grid then was subdivided into 1-ha strips. A random number generator in Microsoft Excel was used to choose one of the three 1-ha strips from each 3-ha grid. Maximum length of a strip line transect was 536 m and each transect was >15 m apart. The surveyor began at the designated starting point of each transect and counted every mound, within 7.5 m, right or left of the transect line while walking to the end point of each transect (Cortez et al. 2013). A Trimble (Trimble, Sunnyvale, California, USA) GPS unit (model GeoExplorer III DGPS with beacon receiver) was used to stay on the transect line and record suspected burrow system locations. The number of mounds within each suspected burrow system was recorded.

Habitat Quality Sampling. From the line transects, we located five 1-ha plots in zero gopher density (0 mounds/ha), low gopher density (25 to 50 mounds/ha), intermediate gopher density (75 to 150 mounds/ha), and high gopher density (>200 mounds/ha). A gap was intentionally left between each level so that the categories would be discrete. Once the 20 plots were determined, we created 20 random points (n = 400) within each plot for vegetation and soil sampling. The random points were created using Hawthorne's Analysis Tools 3.08 (Beyer 2004) in ArcGIS 9.1. A 0.25 m^2 quadrat was used at each point to determine plant species composition. Entire plants (above- and below-ground portions) were collected, identified by species, and placed into paper bags. In the laboratory, the plants were washed to remove soil. After washing, the plants were separated into above-ground parts and roots and dried at 40°C for 48 hours. After drying, above-ground parts and roots were weighed to the nearest 0.01 g. Plant samples were analyzed for crude protein (CP), energy, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL). Dry matter was determined by heating 1 g of ground sample to 105°C for 24 hours. Plant samples (3.0 g) were sent to the Texas A&M University Soil, Water & Forage Testing Laboratory in College Station, Texas, to determine the crude protein. Crude protein was estimated by the Kjeldahl method, which quantifies the percent nitrogen in the sample (protein content = 6.25 x (total N)) (Maynard et al. 1979). Energy content was determined using a bomb calorimeter with benzoic acid as a standard. Samples were ashed in a muffle furnace for 16 hours at 500°C. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed as described by Van Soest et al. (1991). Values of NDF, ADF, and ADL were corrected for ash content.

The plant species diversity (Simpson's Index) (Krebs 1989), species richness (number of species), and density were calculated for each quadrat of each plot. The density was calculated by dividing the sum of plant frequencies by the size of the quadrat (0.25m^2) and multiplying by 4, to determine density per m^2.

Soil samples (5.0 g) were taken within each quadrat after the vegetation was removed. The soil was analyzed for pH, conductivity, nitrate nitrogen ($N0_3$-N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), and sodium (Na). The soil analysis was conducted by the Texas A&M University Soil, Water, & Forage Testing Laboratory in College Station, Texas. The samples were compared between gopher densities and between above- and below-ground plant parts. Data were analyzed by a completely randomized design with sampling error using analysis of variance (ANOVA) (SAS Institute 1989). Each pair of means was analyzed using Tukey's studentized range (HSD) test when a significant ($P < 0.05$) F-test was noted.

Above-ground and below-ground plant data was compared with a paired t-test. Plant frequency of occurrence was analyzed by chi-square analysis.

RESULTS

Soil Properties. Calcium, Mg, S, and Na compounds significantly differed ($F > 3.51$, $P <$ 04) between gopher densities, while soil conductivity, pH, $N0_3$-N, P, and K compounds did not differ ($P > 0.07$) between gopher densities (Table 1). Areas of zero gopher density had significantly higher concentrations of Ca, Mg, S, and Na compounds than the areas where gophers were at higher density levels (Table 1).

Plant Community Parameters. Forty-four (13 grasses, 29 forbs, two woody species) vascular plant species constituting 979 plants were identified within quadrats of the varying gopher densities (Table 2). The most predominant grass species were *Cynodon dactylon* (44%), *Cenchrus spinifex* (20%), *Urochloa maxima* (11%), and *Cenchrus ciliaris* (10%), while the predominant forbs were *Acalypha radians* (20%), *Phlya strigulosa* (12%), *Indigofera miniata* (11%), and *Rhynchosia americana* (10%). One native grass, *Cenchrus spinifex*, was found to increase in frequency as the pocket gopher density increased ($\chi^2 = 30.6$, $P < 0.001$). *Cenchrus spinifex* occurred more often than expected in high density plots, while occurred less often than expected in zero density plots. Three introduced grass species, *Cenchrus ciliaris* ($\chi^2 = 12.6$, $P < 0.01$), *Sorghum halepense* ($\chi^2 = 19.7$, $P < 0.001$), and *Stenotaphrum secundatum* ($\chi^2 = 8.3$, $P < 0.05$) occurred more often than expected in low gopher density plots. Most of the variation in *Cenchrus ciliaris* occurred between low (46%) and high (46%) gopher densities. *Urochloa maxima* ($\chi^2 = 24.2$, $P < 0.001$) occurred more often than expected when gophers were absent. The most variation occurred between zero (43%) and intermediate (55%) gopher densities. Three halophytes or salt tolerant plants, *Monanthochloe littoralis* ($\chi^2 = 14.4$, $P < 0.005$), *Salicornia virginica* ($\chi^2 = 24.0$, P < 0.001), and *Suaeda linearis* ($\chi^2 = 9.0$, $P < 0.05$) occurred more often than expected in zero density plots. *Quercus virginiana* ($\chi^2 = 42.0$, $P < 0.001$) also occurred more often than expected in low density plots. No differences were observed ($F < 1.74$, $P > 0.20$) in plant species richness, diversity, or density among areas of various gopher mound densities (Table 1). Areas without gopher mounds had less overall vegetation biomass ($F = 4.9$, $P < 0.0001$) and below-ground biomass ($F = 8.0$, $P < 0.0001$) than plots with gophers (Table 1). Above-ground biomass was greater ($F = 6.8$, $P < 0.0001$) in areas with intermediate and high gopher mound densities than areas with low and zero mound densities (Table 1).

Plant Nutrients. No differences ($F < 1.75$, $P > 0.20$) were observed in DM, NDF, ADF, ADL, protein, or energy values between areas of various gopher mound densities (Table 1). Significant differences were found between above- and below-ground nutritional components (Table 3). Every nutrient category except dry matter and acid detergent lignin was greater in above-ground samples (*t*-statistic > 2.7, $P < 0.02$).

Table 1. Habitat characteristics of soil, plants, and vegetation nutritional analyses from areas of four gopher densities within Naval Air Station-Corpus Christi during summer (June – August), 2006.

	Maritime pocket gopher mound densities[1]									
	Zero		Low		Intermediate		High		ANOVA	
Habitat Parameters	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*-Value	P-Value
Soil										
pH	7.7A[2]	0.2	7.0A	0.3	7.4A	0.2	7.2A	0.2	1.39	0.28
Conductivity	418.6A	153.4	183.0A	23.9	154.2A	28.0	223.8A	52.6	2.06	0.15
$N0_3N$	9.6A	2.5	4.4A	0.4	5.6A	0.6	5.6A	0.9	2.77	0.07
Phosphorus	59.4A	25.1	46.4A	15.4	32.4A	7.3	43.8A	7.1	0.51	0.68
Potassium	319.6A	113.8	210.2A	52.6	133.0A	31.4	142.4A	38.4	1.63	0.22
Calcium	5780.4A	726.8	2555.8B	924.0	2734.0B	455.5	1860.0B	348.5	7.08	0.003
Magnesium	339.8A	76.3	172.4AB	42.2	129.4B	35.8	106.0B	28.9	4.59	0.02
Sulfur	48.0A	9.8	18.4B	3.0	17.0B	1.3	16.0B	1.0	8.84	0.001
Sodium	266.4A	56.4	172.8A	5.3	144.6B	6.9	162.0AB	11.6	3.51	0.04
Plants										
Richness	9.4A	1.4	12.2A	1.1	13.0A	1.1	11.2A	1.0	1.74	0.20

Diversity	5.2A	0.7	6.3A	0.5	7.3A	1.2	6.8A	0.7	1.26	0.32
Density	188.0A	24.6	210.4A	11.5	218.4A	12.8	171.2A	19.2	1.46	0.26
Overall biomass	33.7A	2.2	38.3B	5.2	43.8B	2.4	55.8B	3.5	4.91	0.0001
Above-ground	26.0A	2.0	26.5A	4.4	30.9AB	1.6	39.2B	2.8	6.81	0.0001
Below-ground	7.7A	0.6	13.5B	1.8	12.9B	1.2	16.6B	1.5	7.96	0.0001
Nutritional[3]										
DM	92.2A	0.4	92.5A	0.3	91.3A	0.5	92.1A	0.2	1.75	0.20
NDF	62.3A	2.7	60.0A	3.5	60.4A	2.0	61.1A	5.1	0.08	0.97
ADF	33.3A	1.7	33.5A	3.1	33.3A	1.2	32.3A	2.2	0.07	0.98
ADL	5.7A	0.4	7.2A	1.2	5.6A	0.3	5.2A	0.5	1.59	0.23
Protein	6.8A	1.0	6.8A	0.5	7.2A	0.3	7.1A	0.4	0.12	0.95
Energy	3522.2A	109.6	3619.2A	174.9	3569.9A	116.7	3621.1A	200.2	0.09	0.96

[1]Gopher mound densities of zero = no gopher mounds, low = 25 to 50 mounds/ha, intermediate = 75 to 150 mounds/ha, and high = > 200 mounds/ha.
[2]Means with the same capital letter are not different within a row (P > 0.05).
[3]Nutritional components are DM = dry matter (%), NDF = neutral detergent fiber (%), ADF = acid detergent fiber (%) , ADL = acid detergent lignin (%), and protein (%). Energy is in kcal/g.

Table 2. Plant species and frequency of occurrence on four gopher densities within Naval Air Station-Corpus Christi during summer (June – August), 2006.

	Maritime pocket gopher mound densities[1]					
Plant Species	Zero	Low	Intermediate	High	χ2	P-Value
Grass						
Cyndon dactylon	55	56	50	51	0.6	0.9
Cenchrus spinifex	6	21	31	40	30.6	0.001
Cenchrus ciliaris	10	21	15	4	12.6	0.01
Urochloa maxima	25	12	0	16	24.2	0.001
Paspalum monostachyum	11	3	8	3	7.3	0.1
Sorghum halepense	0	14	3	5	19.7	0.001
Eragrostis secundiflora	1	6	0	1	11.0	0.025
Stenotaphrum secundatum	1	4	0	0	8.3	0.05
Monanthochloe littoralis	5	0	0	0	14.4	0.005
Spartina patens	0	0	4	0	12.0	0.01
Chasmanthium latifolium	0	0	0	3	9.0	0.05
Aristida purpurea	0	0	1	0	3.0	0.5
Bothriochloa laguroides.	0	0	1	0	3.0	0.5
Forb						
Acalypha radians	15	14	34	29	13.2	0.005
Phyla strigulosa	14	15	18	8	3.8	0.5
Indigofera miniata	11	13	16	12	1.1	0.9
Rhynchosia americana	15	8	18	8	6.2	0.1
Commelina elegans	4	3	18	5	19.8	0.001
Richardia brasiliensis	0	13	6	8	12.8	0.005
Mimosa strigillosa	8	7	4	2	4.3	0.25
Croton capitatus	3	6	6	3	2.0	0.75
Erigeron procumbens	2	10	4	0	14.0	0.005
Sphaeralcea lindheimeri	4	1	5	3	2.7	0.5
Astragalus nuttallianus	13	0	0	0	39.6	0.001
Zinnia acerosa	0	0	8	4	14.6	0.005
Portulaca pilosa	6	5	0	0	11.1	0.025
Salicornia virginica	8	0	0	0	24.0	0.001
Ipomoea trichocarpa	0	2	5	0	9.5	0.025
Neptunia pubescens	0	5	2	0	9.5	0.025
Philoxerus vermicularis	2	0	3	2	2.7	0.5
Lantana camara	5	0	0	0	15.0	0.005

Helianthus praecox	4	0	0	1	8.6	0.05
Thymophylla tenuiloba	0	2	2	0	4.0	0.5
Croton glandulosus	0	3	0	0	9.0	0.05
Suaeda linearis	3	0	0	0	9.0	0.05
Gaillardia pulchella	0	0	3	0	9.0	0.05
Palafoxia texana	0	2	0	0	6.0	0.25
Cooperia drummondii	1	1	0	0	2.0	0.75
Solanum elaeagnifolium	0	0	1	1	2.0	0.75
Lepidium austrinum	1	0	0	0	3.0	0.5
Phlox drummondii	0	0	1	0	3.0	0.5
Waltheria indica	1	0	0	0	3.0	0.5
Trees, shrubs & woody						
Schrankia latidens	1	2	1	8	11.2	0.02
Quercus virginiana	0	14	0	0	42.0	0.001

[1]Gopher mound densities of zero = no gopher mounds, low = 25 to 50 mounds/ha, intermediate = 75 to 150 mounds/ha, and high = > 200 mounds/ha.

Table 3. Comparison of nutritional components between above-ground vegetation and below-ground vegetation within Naval Air Station-Corpus Christi during summer (June – August), 2006.

Nutritional Component[1]	Above-ground	Below-ground	SE	t-statistic	*P*-value
DM (%)	92.0	94.1	0.3	6.14	0.001
NDF (%)	60.9	47.5	3.3	4.06	0.001
ADF (%)	33.1	27.9	1.9	2.81	0.011
ADL (%)	5.9	7.6	0.6	2.72	0.014
Protein (%)	7.0	5.3	0.3	5.10	0.001
Energy (kcal/g)	3583	2940	169	3.81	0.001

[1]Nutritional components are DM = dry matter, NDF = neutral detergent fiber, ADF = acid detergent fiber, and ADL = acid detergent lignin.

DISCUSSION

The Maritime pocket gopher is restricted to the deep sandy soils of Kleberg and Nueces counties, between Baffin Bay and Flour Bluff (Williams 1982; Williams and Genoways 1981). Williams (1982) also noted that rocky, silt loam or clay soils can create barriers to this species because of the difficulty in digging tunnels in such soil types. Only two soil types are found on NAS-CC, Galveston and Mustang fine sand and dredge spoils, the latter of which consists of clay loam sediment found on the seabed (NRCS 1960). The soil in three of the five zero mound density plots consisted mainly of dredge spoils (NRCS 1960). Therefore, the non-detection of MPG in zero density plots may be due to the soil type in these plots. In addition, dredge spoils contained shells (i.e.: oysters, snails, etc.); therefore, the large amounts of calcium, magnesium, sulfur, and sodium compounds found in the zero density plots can be attributed to the dredge spoils as well. The non-detection of gophers in these plots also could have been due to the high salt or sodium chloride content in the soil. High salt content limits the vegetation to salt-tolerant plant species. There has been no documentation of MPG utilizing salt-tolerant plants. Their diet has been reported to consist of grass species including *Paspalum*, *Cynodon,* and *Cenchrus* and forbs from the genus *Helianthus* (Davis and Schmidly 1994).

In addition, four of the five zero density plots were fragmented by urban development. These islands of habitat were either surrounded by wide swaths of concrete, asphalt, and buildings, or by inhospitable soils for digging (i.e. clay loam). Through personal observations, MPG were able to burrow under roads and areas with thin layers of dredge spoils, but the lack of tunnel openings in wide swaths of concrete and asphalt appeared to be a formidable barrier.

Pocket gophers are generalist herbivores (Williams and Cameron 1986). As generalists, pocket gopher densities should not be affected by plant richness or plant diversity. In other studies, gopher disturbance (i.e. gopher tunnels or mounds) did not have an effect on plant species diversity (Rezsutek and Cameron 2000) nor plant species richness (Williams and Cameron 1986), nor did they have an effect in our investigation. Although past studies focused on how pocket gophers affect plant communities, this study concentrated on whether plant community characteristics affected pocket gopher density. MPG preference for areas with high frequencies of *Cenchrus spinifex* and the fact that gopher density increased as *C. spinifex* frequency increased probably supports an overall preference by MPG for native species. In fact, the avoidance of exotic grasses by MPG further endorses this hypothesis. The avoidance of the halophytes also may be due to the inability of MPG to reach salt marsh habitat. The salt marsh is bordered by a mesquite forest and a drainage ditch, both of which can be formidable barriers for pocket gophers. Live oak avoidance is attributed to probable difficultly of digging around thick tree roots and to reduction of palatable forbs and grasses in oak habitat.

Gopher density increased as the above-ground, below-ground, and overall biomass increased, which differs from Williams and Cameron (1986) who found that frequency, cover, and biomass increased in absence of pocket gophers. Williams et al. (1986) suggested that pocket gopher mounds enhanced plant growth, which may have occurred at our study sites. Furthermore, Ward and Keith (1962) and Williams and Cameron (1986) suggested that important foods of pocket gophers were the most abundant, palatable species, which supports the study's findings that MPG densities were greater in areas with greater vegetation biomass (i.e. more available food).

The lack of variation in the nutritional composition of vegetation found among the gopher density plots may be attributed to a lack of knowing when pocket gophers arrived at a plot. Patch use of optimal foraging theory suggests that an animal will remain in its current patch until the nutritive value of the patch falls below the value of the overall habitat (Pyke et al. 1977). Pocket gophers at the high density plots may have been in the area for a period of time and already eaten the most nutritious plants before we sampled the vegetation, thus, giving the appearance of a decreased amount of nutrients within the plot. Consequently, this would decrease the amount of the variation within nutritional parameters among gopher density plots.

The differences found in the nutritional analysis of above-ground and below-ground vegetation samples may not be very indicative of gopher densities. *Geomys attwateri* consume above-ground parts of plants by pulling entire plants below ground

(Williams and Cameron 1986). The MPG has similar grazing behavior. Numerous underground caches were found that included whole plants of grass and forb species. It is unknown, however, just how much of the MPG diet consists of aboveground parts of plants. A food habits study for MPG is warranted. According to Vleck (1979), burrowing can require 360 to 3,400 times as much energy as moving the same distance across the surface. Therefore, it is likely that MPG utilize a substantial amount of the higher energy above-ground vegetation to meet its fossorial energy requirements. The lower acid detergent lignin (ADL) in the above-ground vegetation also may allow for better digestion. Lignin is totally indigestible; therefore, higher levels of lignin reduces digestibility. Conversely, the lower NDF and ADF in the below-ground vegetation may allow pocket gophers greater intake and digestibility. High NDF and ADF levels result in reduced intake and decreased digestibility. Because the greatest MPG densities occurred in areas with the greatest plant biomass and that no significance was observed in the nutritional parameters between MPG densities, our results concur with Williams and Cameron (1986) that pocket gophers are generalist herbivores and that the most important foods of pocket gophers are the most abundant palatable species, which also was reported by Ward and Keith (1962).

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