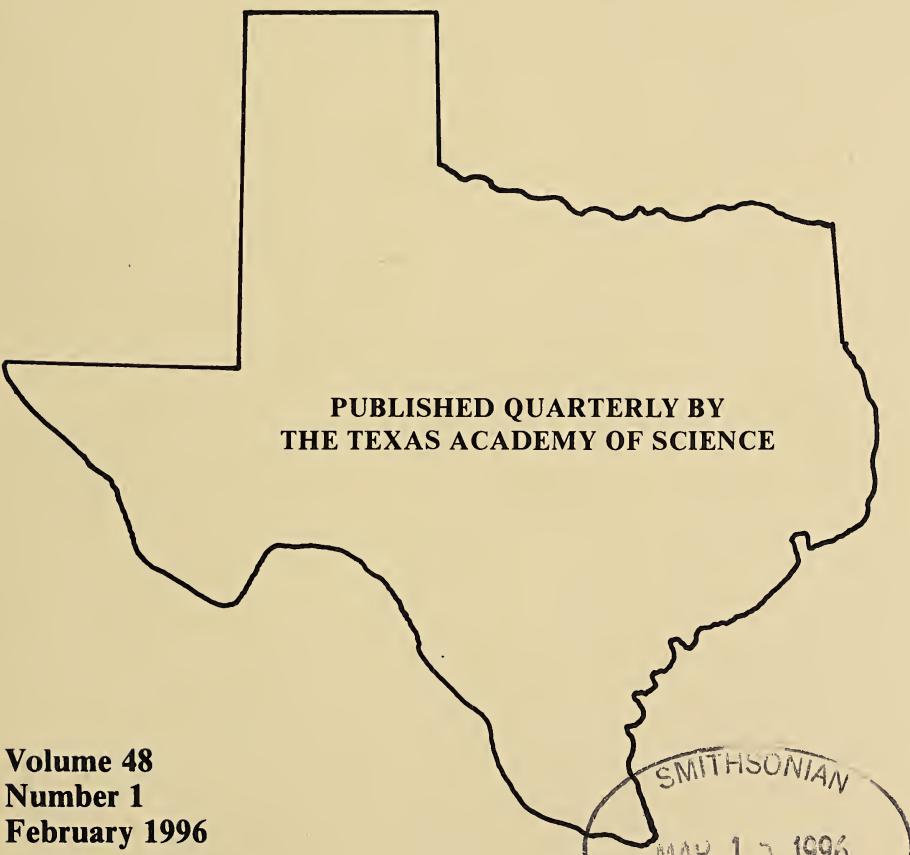




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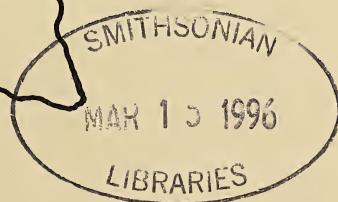
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DISTRIBUTION, NATURAL HISTORY AND STATUS OF THE PALO DURO MOUSE, *PEROMYSCUS TRUEI COMANCHE*, IN TEXAS

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Abstract.—Extensive live-trapping along the escarpment of the Llano Estacado in the Texas Panhandle was utilized to determine the current distribution of the Palo Duro mouse (*Peromyscus truei comanche*). The results of this study support the premise that the current range of this taxon is limited to Randall, Armstrong and Briscoe counties of northwestern Texas. Furthermore, this species occurs only near juniper (*Juniperus* sp.) associated slopes of the Llano Estacado within this three-county area. The restricted distribution and habitat, as well as additional aspects of the natural history of this mouse are discussed.

The Palo Duro mouse (*Peromyscus truei comanche*) is known to occur only in select habitat of the northcentral Texas Panhandle. This taxon is ecologically linked with rocky, juniper (*Juniperus* sp.) associated slopes of the large mesa of the Southern High Plains known as the Llano Estacado (Blair 1943; Schmidly 1973; Johnson & Packard 1974; Zimmerman & DeWalt 1990; Choate 1991; Choate et al. 1991). Its nearest relative, the piñon mouse (*Peromyscus truei truei*), occurs in areas of juniper and piñon pine (*Pinus edulis*) on the Llano Estacado of extreme western Texas and eastern New Mexico (Choate 1991; Choate et al. 1991). Blair (1950) suggested that *P. truei comanche* became isolated in the Texas Panhandle with the general warming following the Wisconsinian glacial period (ca. 10,000 YBP). As temperatures increased, vegetation changed along the caprock of the Llano Estacado. This resulted in stretches of the northern caprock that lack significant stands of juniper and, therefore, are ecologically unsuitable for *P. truei*. As a consequence, an ecological barrier approximately 120 km in length, developed and *P. truei comanche* evolved independently of *P. truei truei*.

Because of its limited distribution, the Palo Duro mouse presently is regarded as threatened (protected nongame) by the Texas Parks and Wildlife Department and is a candidate for Category 2 listing by the U.S. Fish and Wildlife Service. Therefore, current data pertaining to its distribution and natural history are vital in assessing its status.

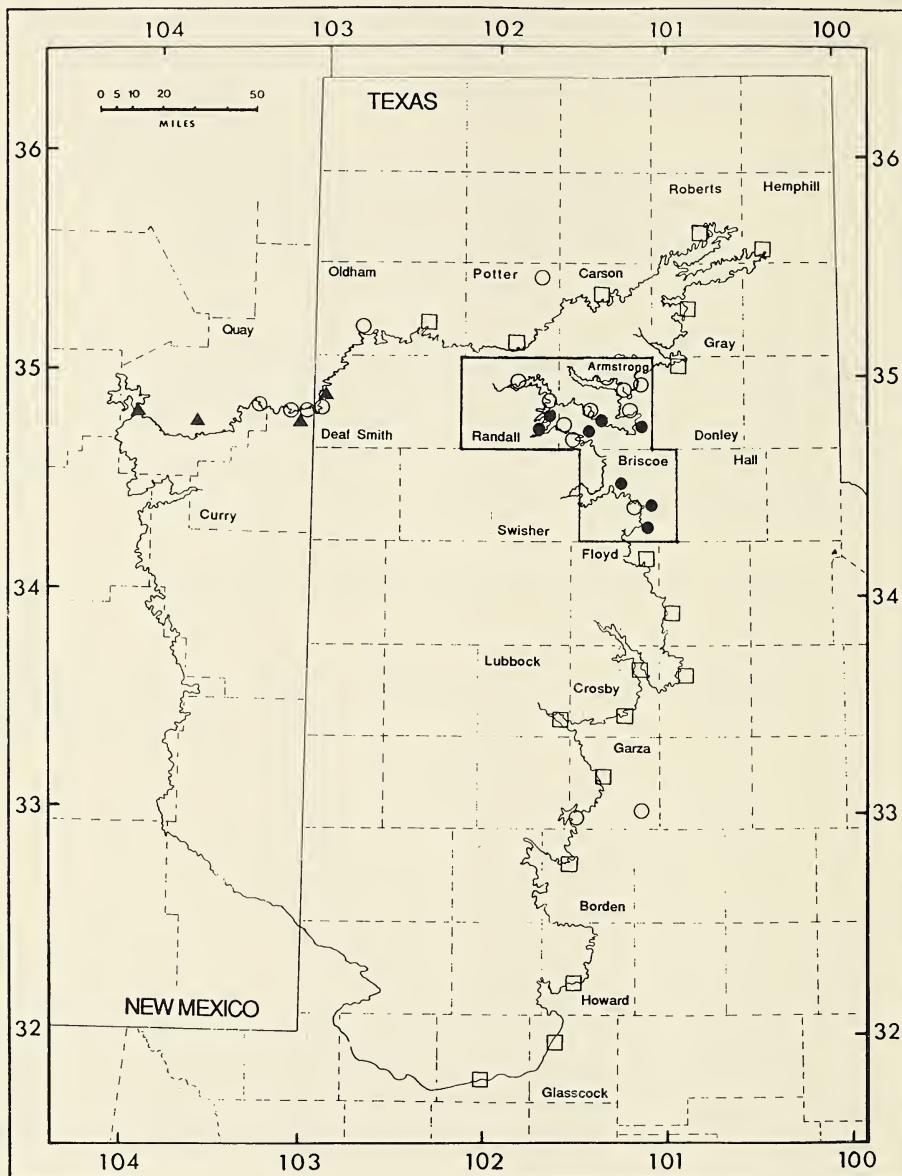


Figure 1. Map of the southern Great Plains of New Mexico and Texas showing the Llano Estacado. Shown are trapping localities. Solid circles represent localities where *Peromyscus truei comanche* was collected during 1992. Open circles represent localities which were trapped during 1992 but failed to yield *P. truei*. Closed triangles are trap-sites at which *Peromyscus truei truei* was collected. Open squares are localities that were trapped during the last five years and failed to yield either *P. truei comanche* or *P. truei truei*. The highlighted three county area in the northern Panhandle of Texas represents the only verified populations of *P. truei comanche*.

MATERIALS AND METHODS

Specimens were captured using Sherman live-traps baited with rolled oats. At selected sites at or near the breaks of the Llano Estacado, traps were set at 10 m intervals along transects 400-500 m in length. Trap sites consisted of areas that appeared to represent prime habitat for the species (steep, rocky, juniper-associated slopes), as well as areas which appeared to be less than ideal (gentle slopes or flat areas near the base of slopes).

Traps were set approximately 1.5 hours before sundown and retrieved approximately one hour after sunrise the following morning. Animals acquired were identified and voucher specimens (standard museum skin and skull) were prepared. From a sample of eight *P. truei comanche* from Armstrong County, liver, heart, kidney, and skeletal muscle were collected and stored in an ultracold freezer. All tissues (TK 40209-40216) and voucher specimens are deposited in The Museum, Texas Tech University. In addition to these specimens, other specimens housed at The Museum provided data for this study.

RESULTS AND DISCUSSION

Distribution.—During the period from May to August 1992, 25 localities were trapped along or near the breaks of the Llano Estacado in Texas and New Mexico. While conducting related studies during the past five years, considerable time was spent sampling south of Briscoe County along the eastern edge of the escarpment, as well as the northern Llano Estacado of Texas and New Mexico. Based upon the above trapping efforts, *P. truei comanche* is known for certainty to occur only within a three-county area in northwestern Texas (Fig. 1).

Earlier reports on the range of this mouse have shown a much more southerly distribution (Zimmerman & DeWalt 1990). However, records of *P. truei comanche* from south of Briscoe County have subsequently proven to be those of *Peromyscus attwateri* (cf. Choate 1991). In addition, a single mouse identified as *P. truei comanche*, which was collected in Swisher County was examined. This specimen (CMNH 89256), which is deposited with The Carnegie Museum of Natural History, also appears to be *P. attwateri*. A list of known specimens of *P. truei comanche* (with collection locality and site of deposition), including specimens taken during this study, is presented in Appendix 1.

Table 1. Summary of successful sampling efforts for *Peromyscus truei comanche* from May to August 1992.

Date	County	Trap nights	No. of specimens collected
9 June 1992	Armstrong	200	8
30 June 1992	Randall	170	1
24 July 1992	Randall	230	13
29 July 1992	Briscoe	150	3
30 July 1992	Briscoe	250	8
11 Aug. 1992	Armstrong	200	1
19 Aug. 1992	Armstrong	280	2
20 Aug. 1992	Armstrong	230	2
21 Aug. 1992	Briscoe	250	4
Totals		1960	42

Relative abundance.—During this study, 6,770 traps were set on 36 different occasions; nine of which were successful in yielding a total of 42 specimens of Palo Duro mice (Table 1). Success rates (number of *P. truei comanche* taken per 100 trap nights) ranged from zero percent to 5.65%. The overall combined success rate for all 6,770 trap nights was 0.66%. This low figure does not accurately reflect the "real" abundance of Palo Duro mice, because, as previously discussed, many traps were set in areas which were believed to be of marginal quality. The average success rate for the nine traplines that yielded at least one *P. truei comanche* was 1.68. The highest figure (5.65%) is reflective of populations occupying prime habitat. This prime habitat occurs within the boundaries of Palo Duro Canyon State Park and, therefore, is under state control. Observations made during this study support the premise that where prime habitat occurs, there is no scarcity of Palo Duro mice. In contrast, poor or marginal habitats appear to support few or no mice.

Habitat.—All 42 specimens of Palo Duro mice taken during this study were found along the northeastern escarpment of the Llano Estacado. Twenty-seven of these mice (64%) were taken on sparsely-vegetated, juniper-clad, steep, rocky slopes of red sandstone, often interspersed with layers of gypsum. This geologic formation sometimes is referred to as Spanish skirt. Eleven Palo Duro mice (26%) were obtained from moderately sloping or flat mesquite-grassland with limited juniper at the base of steep sandstone slopes. Three specimens (7%) were captured on steep sandstone slopes completely devoid of vegetation. Finally, a single individual (2%) was acquired from level juniper-grassland above and adjacent to a steep, rocky break.

Vegetation (other than juniper) associated with Palo Duro mice included "brush" species such as skunkbush (*Rhus* sp.), mesquite (*Prosopsis* sp.), saltbush (*Atriplex* sp.), scrub oak (*Quercus* sp.), and catclaw (*Mimosa* sp.). Common grasses and understory plants included hairy grama (*Bouteloua hirsuta*), sideoats grama (*B. curtipendula*), buffalograss (*Buchloë dactyloides*), ragweed (*Ambrosia* sp.), yucca (*Yucca* sp.), prickly pear (*Opuntia* sp.), tasajillo (*Opuntia* sp.), lovegrass (*Eragrostis* sp.), sand bluestem (*Andropogon* sp.), and little bluestem (*Schizachyrium* sp.).

Surface soils from near Quitaque, Briscoe County, where Palo Duro mice were frequently captured, are referred to as Quinlan-Burson-Obaro associations. Geiger & Mitchell (1977) described these soils as "very shallow to deep, gently sloping hilly and steep, moderately permeable and moderately rapidly permeable loams on uplands."

In Armstrong County, Palo Duro mice were taken on Broken Lands-Quinlan associations. These are described as "rough lands with shallow to moderately steep, moderately permeable loamy soils. They consist of strongly dissected caliche breaks and redbed breaks" (Anonymous 1977a).

In Randall County, *P. truei comanche* was affiliated with Rough Broken Land-Potter-Quinlan-Woodward associations. These soils are described as "rough broken land and shallow to moderately deep, moderately permeable, loamy, and gravelly soils. They consist of steep escarpment, sandstone ledges, bluffs, steep slopes, and highly dissected redbeds" (Anonymous 1977b).

Mammals collected at the same localities as *P. truei comanche* were as follows: silky pocket mouse (*Perognathus flavus*), hispid pocket mouse (*Chaetodipus hispidus*), deer mouse (*Peromyscus maniculatus*), white-footed mouse (*P. leucopus*), Texas mouse (*P. attwateri*), hispid cotton rat (*Sigmodon hispidus*), and the white-throated woodrat (*Neotoma albicula*).

Reproductive biology.—Reproductive data derived from the 42 specimens of *P. truei comanche* captured during this study and from museum specimens housed at Texas Tech University are presented in Table 2. For the 14 gravid females examined, the mean number of embryos was 2.8 (mode=3; min.=1; max.=4). This average is slightly lower than that reported for other subspecies of piñon mice (Hoffmeister 1981). Gravid females examined during this study were taken during

Table 2. Reproductive data for *Peromyscus truei comanche* from northwestern Texas.

Date	Male	Female (crown-rump length)
7 April 1992	-	Two Specimens one w/1 embryo (13 mm) one w/2 placental scars
15 May 1992	-	One Specimen w/o embryos
10 June 1992	Two Specimens testes 8 by 14 mm testes 7 by 12 mm	Five Specimens one w/o embryos one w/2 embryos (6 mm) one w/3 embryos (6 mm) one w/2 embryos (12 mm) one w/2 embryos (23 mm)
16 June 1992	Two Specimens w/testes 5 by 9 mm	Two Specimens w/o embryos
25 July 1992	Seven Specimens testes 6 by 12 mm testes 7 by 12 mm testes 7.5 by 12 mm two specimens with testes 7 by 13 mm testes 8 by 11 mm testes 8 by 13 mm	Three Specimens one w/o embryos one w/3 embryos (25 mm) one post-lactating
30-31 July 1992	Five Specimens testes 6 by 8 mm testes 6 by 11 mm testes 6 by 13 mm testes 7 by 13 mm testes 4 by 10 mm	Eleven Specimens seven w/o embryos one w/3 embryos (9 mm) one w/4 embryos (10 mm) one w/4 embryos (18 mm) one w/3 embryos (19 mm)
20-22 August 1992	Three Specimens testes 6 by 11 mm testes 8 by 13 mm testes 8 by 14 mm	Four Specimens one w/4 embryos (12 mm) one w/3 embryos (15 mm) one w/3 embryos (17 mm) one w/3 embryos (24 mm)

April, June, July and August. In addition, Zimmerman & DeWalt (1990) reported evidence of gravid females in March and October. Males examined during this study were in reproductive condition during June, July, and August, as indicated by testicular development (Table 2).

All members of the genus *Peromyscus* apparently breed whenever environmental conditions are suitable for the successful rearing of young (Millar 1989). Available evidence suggests that for the Palo Duro mouse, this period occurs between mid-March and early October.

Pelage.—Juvenile Palo Duro mice displaying a uniform gray pelage were observed in the population during April, June and July. Seasonal molting of adults was noted on specimens taken in April, May, June and

July. Hoffmeister (1951) infers that *P. truei* adults typically molt once in the fall, but also notes that adult molting has been observed in March and June. He explains that these atypical molts may indicate (1) an early or late adult molt, (2) molting in adults occurs at various times throughout the year, or (3) adult molting occurs twice a year.

Threat assessment.—There are no known population-decimating threats to the Palo Duro mouse at present. There is no evidence that predation or disease are a threat to these mice. Scientific collection is not intense enough to pose a problem. There is no interest in these mice as pets and, therefore, they are not collected as such.

At this time, there are no significant threats to the specific habitat of the Palo Duro mouse. Most of the habitat in which these mice are found is of no agricultural value, and adequate vegetation for grazing is lacking. Moreover, there are two state parks within the geographic range of this subspecies, which serve as refugia. It is expected that populations will maintain current levels given present land-use practices.

CONCLUSIONS AND RECOMMENDATIONS

Peromyscus truei comanche is a taxon with a very limited distribution, apparently being restricted to the juniper-clad breaks along the northeastern edge of the Llano Estacado in Randall, Armstrong, and Briscoe counties, Texas. Nevertheless, based on relative abundance figures, it does not appear to be uncommon where it occurs within this range. However, data regarding population sizes and trends, as well as factors affecting reproduction are lacking, and long-term studies to assess these areas are suggested.

Also wanting are ecological data addressing the restricted distribution of this mouse. For example, little is known about the food habits of the Palo Duro mouse. Zimmerman & DeWalt (1990) suggest that it consumes juniper, mesquite and prickly pear seeds, as well as ripened juniper fruits, but a detailed investigation is needed to determine if diet plays an important role in limiting the distribution of this taxon. In addition, there is limited information as to whether competition from congeneric species might be displacing *P. truei comanche* from suitable habitat outside its range. According to Choate (1991), *Peromyscus attwateri* also is partial to the juniper breaks of the Llano Estacado. During this study, 30 specimens of *P. attwateri* were collected from seven localities, all of which were similar in habitat to that which yielded *P. truei comanche*. Interestingly, only two sites yielded both

taxa. Data collected during this study are insufficient to address the ecological relationships between *P. truei comanche* and *P. attwateri* (or any other taxa), as this was not the design or intent of this study. However, this noticeable trend would appear to justify future studies to determine if competition with other species of *Peromyscus* (especially *P. attwateri*) is limiting the distribution of *P. truei comanche*.

Finally, data pertaining to parasites and diseases of *P. truei comanche* are lacking. *Peromyscus truei*, in general, has been reported to be infected with *Hymenolepis horrida* (a tapeworm), *Protospirura numidica*, and *Gongylonema peromyisci* (both parasitic nematodes) (Whitaker 1968). *Peromyscus truei* also is known to harbor the tick *Ixodes pacificus* (cf. Whitaker 1968), a principal vector of *Borrelia burgdorferi*, the etiological agent of Lyme's disease (Burgdorfer et al. 1985). In addition, *P. truei* has been linked to *Yersinia pestis* (the plague bacillus) infection (Allred 1952), and recently has been shown to have a significant rate of hantavirus infection in the western United States (Stone 1993). Examination of *P. truei comanche* for these, and other detrimental parasites may shed some insight as to its status, as well as its potential as a public health hazard.

ACKNOWLEDGMENTS

We commend the late Dr. J. Knox Jones, Jr. and Peggy Horner for initiating this project. We thank Burhan Gharaibeh for his assistance in the field. Appreciation is extended to Dr. Duane Schlitter and Suzanne McLaren of The Carnegie Museum of Natural History for providing a specimen that required examination. The Texas Parks and Wildlife Department funded this project and issued necessary scientific collecting permits.

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Appendix 1. List of known specimens of *Peromyscus truei comanche* and site of specimen deposition.

Collection Locality	N	Deposition Site (Reference if applicable)	
Armstrong County			
27 mi SE of Amarillo	5	TNHC	(Choate 1991)
15 mi S, 9 mi E of Claude	1	TTU	
16 mi S, 10 mi E of Claude	1	TTU	
20 mi SE of Canyon	1	MWSU	(Choate 1991)
6 mi E of Wayside	1	TTU	
0.75 mi N, 6.25 mi E of Wayside	10	TTU	(this study)
15.5 mi S, 8.5 mi E of Claude	1	TTU	(this study)
15.5 mi S, 1 mi W of Claude	2	TTU	(this study)
Brisco County			
17 mi NW of Silverton, Tule Slope	5	TNHC	(Choate 1991)
Tule Canyon	1	TNHC	(Choate 1991)
6 mi N, 4 mi W of Silverton	19	TTU	
	6	TNHC	(Schmidly 1973)
5 mi N, 6 mi W of Silverton	5	TCWC	(Choate 1991)
	18	UI	(Schmidly 1973)

Appendix 1. (Continued)

Collection Locality	N	Deposition Site (Reference if applicable)	
5 mi N, 1 mi W of Quitaque	6	TTU	
Caprock Canyons State Park	19	TTU	
Caprock Canyons State Park	14	TTU	(this study)
8 mi N, 2.5 mi E of Silverton	1	TTU	(this study)
22 mi E of Tulia, Gill Ranch	11	UMMZ	(Schmidly 1973)
22 mi E of Tulia, Tule Canyon	10	UMMZ	(Blair 1943)
Quitaque	3	UMMZ	(Schmidly 1973)
20 mi S, 5 mi W of Claude	1	UI	(Schmidly 1973)
Randall County			
10-13 mi E of Canyon	2	TTU	
	3	MWSU	(Choate 1991)
	1	WBC	(Choate 1991)
19 mi E of Canyon	1	TTU	
21 mi S of Amarillo	9	TNHC	(Choate 1991)
Palo Duro Canyon State Park	27	TTU	
	13	TCWC	(Choate 1991)
	1	WBC	(Choate 1991)
	8	UNT	(Zimmerman & DeWalt 1990)
	13	TTU	(this study)
9.2-9.5 mi S, 13.7 mi E of Canyon	6	TTU	
Palo Duro Canyon	3	TTU	
	2	MWSU	(Choate 1991)
15 mi E of Canyon	4	*	(Modi & Lee 1984)
27 mi SE of Amarillo, Palo Duro Canyon	7	*	(Tamsitt 1958)
17 mi SE of Washburn, Palo Duro Canyon	1	*	(Tamsitt 1958)
7 mi N, 7.5 mi E of Happy, South Ceta Canyon	1	TTU	(this study)

TTU	The Museum, Texas Tech University
TCWC	Texas Cooperative Wildlife Collection, Texas A&M University
WBC	Wayland Baptist College Museum of Zoology
MWSU	Midwestern State University Collection of Recent Mammals
TNHC	Texas Natural History Collection, University of Texas, Austin
UI	Museum of Natural History, University of Illinois, Urbana-Champaign
UMMZ	Museum of Zoology, University of Michigan
UNT	University of North Texas
*	Site of deposition not stated

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**A SURVEY OF THE
EPILITHIC INTERTIDAL MACROALGAL FLORA
OF FREEPORT, TEXAS**

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Abstract.—The intertidal macroalgal flora of the southwestern jetty adjacent to the discharge of the Colorado River at Freeport, Texas, was surveyed qualitatively on five occasions during a 15 month period from June 1993 to August 1994. The number of species reported from Freeport is increased from a previous total of 11 to 28. Observations on the seasonal occurrence, relative abundance and vertical zonation within the intertidal zone are provided for each species. The intertidal macroalgal flora of Freeport is also compared with that of the Galveston jetties 70 km to the northeast and the Matagorda jetties which are located 70 km to the southwest.

The intertidal macroalgal flora has been well documented along the lower (Baca et al. 1977; 1979; Sorensen 1979) and the central Texas coast (Edwards 1970; Edwards & Kapraun 1973; Kapraun 1980). The intertidal macroalgal flora of the upper Texas coast (Sabine Pass to Matagorda), however, is relatively poorly known.

The intertidal macroalgal flora of the Galveston jetties was surveyed by Lowe & Cox (1978) who reported the presence of 19 species. This study also reported that the Galveston jetty flora was dominated by an *Enteromorpha/Bangia/Gelidium* community in the winter which shifts to a *Cladophora/Bryocladia/Ceramium* community during the summer. Medlin (1984) added *Bryopsis pennata* and Wardle (1992) added *Porphyra leucosticta* to the Galveston flora, resulting in a total of 21 species presently reported. Lowe & Cox (1978) also reported the occurrence of 11 species from the southwestern jetty at the Brazos River discharge south of Freeport and noted the results of an unpublished preliminary survey which was conducted by H. Keatts in 1969. The only other published report on the benthic macroalgal flora along the upper Texas coast to date is that of Boyd & Wardle (1994) who reported the occurrence of eight winter species on the jetty adjacent to the mouth of the Colorado River south of Matagorda. Their results indicate that the flora of the Matagorda jetty during the winter of 1993 was dominated by an *Enteromorpha/Bangia/Bryocladia* community which also included a substantial population of *Lomentaria baileyana*, a red

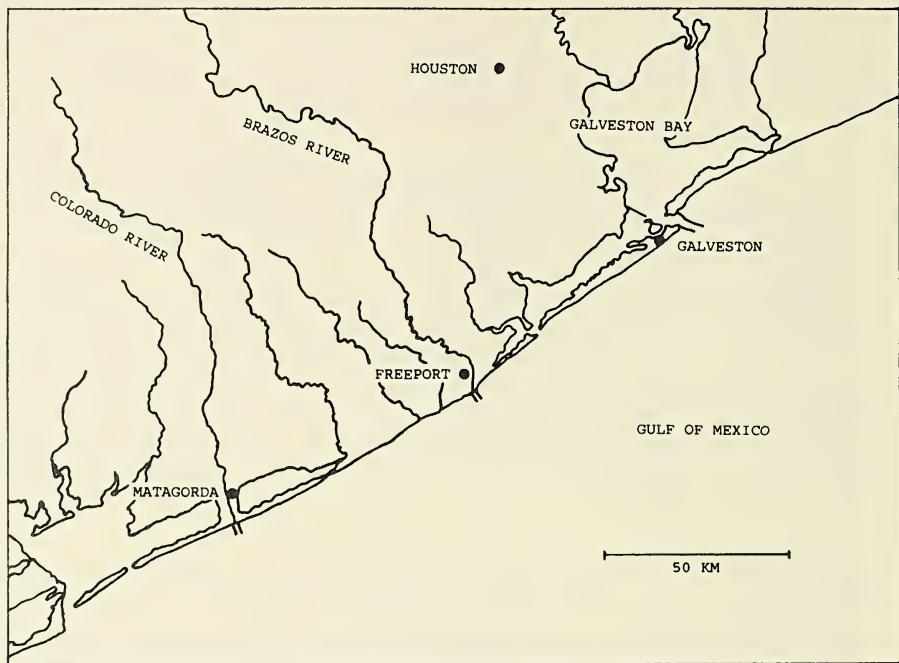


Figure 1. Location of the southwestern jetty at Freeport on the upper Texas coast.

algal species not previously known to occur along the upper Texas Coast.

The objective of this present study was to conduct a four-season qualitative survey of the intertidal macroalgal flora of the Freeport jetty in order to gain a more thorough understanding of the seasonal occurrence, vertical distribution within the intertidal zone, and geographic distribution of the species which occur along the upper Texas coast.

MATERIALS AND METHODS

Five collections of intertidal macroalgae were obtained from the rock jetty located on the southwestern side of the discharge of the Brazos River (known as the Freeport Harbor Channel) into the Gulf of Mexico (Fig. 1). The jetty is approximately 900 meters long, 15-20 m wide, and is primarily composed of roughly cubical granite blocks approximately 1 by 1 by .5 m in dimension. Collections were conducted at

three to four month intervals during a 15 month period from June 1993 to August 1994. Three collecting sites on the jetty were sampled on each occasion: a "channel" station located 450 m from the base of the 900 m jetty on its northeastern side adjacent to the Freeport Harbor Channel, a "tip" station located at the seaward end of the jetty and a "gulf" station located 450 m from the base of the jetty on its southwestern side adjacent to the waters of the Gulf of Mexico.

At each station, separate collections were made from three vertical subzones within the intertidal zone: a "lower" intertidal zone marked by presence of acorn barnacles (*Balanus spp.*) and stunted oysters (*Crassostrea virginica*), a "middle" intertidal zone, marked by the presence of the distinctive star barnacle (*Chthamalus stellatus*) and an "upper" intertidal zone devoid of sessile calcareous animals. Each zone was approximately 1 m in width (varying somewhat with differing angles of slope of individual granite blocks) and was surveyed visually for the presence of macroalgae over a horizontal distance of ten meters. Samples of the fouling community were scraped from the rock surface wherever variations in color and texture provided indication of the presence of different algal species and species assemblages. In view of the limited objectives of this survey, no attempt was made at quantitative sampling.

Samples obtained from each subzone at each station were processed and analyzed using the methods given in Edwards (1970) and species were identified with the aid of the works by Edwards (1970) and Taylor (1972). Nomenclature follows that of Wynne (1986). Salinity was recorded adjacent to each station with an American Optical total solids refractometer. Water temperature was not taken since the relative infrequency of sampling would render such isolated readings rather meaningless. Air temperature readings (U. S. National Weather Service) were reviewed over the sampling period in order to monitor seasonal trends. These were found to be within the normal seasonal range for the 15 month sampling period and no freezing temperatures were recorded during this time period.

RESULTS

Seventeen previously unreported intertidal macroalgal species were recorded from the five collections made during this study. With the addition of the 11 species reported in Lowe and Cox (1978), the total number of species known to occur on the Freeport jetties is now 28 (Table 1).

Table 1. Checklist of intertidal macroalgae previously reported by Lowe & Cox (1978) and presently reported by season during this study from the southwestern jetty at Freeport, Texas. "x" = present.

	Lowe & Cox (1978)	This Study				
		Jun 93	Oct 93	Jan 94	Apr 94	Aug 94
Division Chlorophyta						
<i>Bryopsis pennata</i>	-	-	x	x	-	-
<i>Chaetomorpha linum</i>	x	x	x	x	x	x
<i>Cladophora dalmatica</i>	-	x	x	x	x	x
<i>Cladophora ruchingeri</i>	-	x	x	-	-	-
<i>Cladophora vagabunda</i>	-	x	x	x	-	x
<i>Enteromorpha clathrata</i>	-	x	x	x	x	-
<i>Enteromorpha lingulata</i>	-	x	x	x	x	x
<i>Enteromorpha prolifera</i>	-	-	-	x	x	-
<i>Ulothrix flacca</i>	-	x	x	-	-	-
<i>Ulvella lens</i>	x	-	x	-	-	-
Division Chrysophyta						
<i>Navicula sp. (tubicolus)</i>	-	x	x	-	-	x
Division Phaeophyta						
<i>Giffordia mitchelliae</i>	-	-	-	x	-	-
<i>Giffordia rallsiae</i>	-	x	x	x	-	-
Division Rhodophyta						
<i>Acrochaetium seriatum</i>	-	-	x	-	-	-
<i>Audouinella hoytii</i>	-	-	-	-	-	x
<i>Bangia atropurpurea</i>	x	x	x	x	x	x
<i>Bryocladia cuspidata</i>	x	-	x	-	-	-
<i>Ceramium strictum</i>	x	-	x	x	-	x
<i>Erythrocptelis subintegra</i>	x	x	x	x	x	x
<i>Erythrotrichia carnea</i>	x	x	x	x	x	x
<i>Gracillaria foliifera</i>	x	-	-	-	-	-
<i>Gelidium pusillum</i>	x	x	x	x	x	x
<i>Polysiphonia boldii</i>	-	-	x	x	x	-
<i>Polysiphonia denudata</i>	x	-	-	-	-	-
<i>Polysiphonia tepida</i>	-	-	-	x	-	-
<i>Porphyra leucosticta</i>	-	-	-	x	x	-
<i>Pterocladia bartletti</i>	-	-	-	-	x	-
<i>Stylonema alsidii</i>	x	-	x	x	-	x

Information on the seasonal occurrence, relative abundance and vertical distribution within the intertidal zone is given for each species in the following annotated list:

Division Chlorophyta

Bryopsis pennata Lamouroux.—This non-turf-forming hemispherical species was collected in January and April from the middle and lower zones at all stations as a minor floral component. Medlin (1984) reported this species from Galveston with the same seasonal pattern, zonation and relative abundance. It has not been previously recorded from Matagorda.

Chaetomorpha linum (O. F. Mueller) Keutzing.—This common floral component was present at each station on each sampling date. Although it occurred in all three zones, it was less common in the lower zone. *Chaetomorpha linum* has also been recorded in similar circumstances from Galveston (Lowe & Cox 1978) and Matagorda (Boyd & Wardle 1994).

Cladophora dalmatica Keutzing.—This species was common throughout the year at all stations and was a dominant component during late summer and fall. It was widely distributed vertically in all zones, being especially prevalent in the upper and middle zones. Similar patterns of occurrence for this species have been recorded from Galveston (Lowe & Cox 1978) and Matagorda (Boyd & Wardle 1994).

Cladophora ruchingeri (C. Agardy) Keutzing.—This species was collected from the middle zone on the tip station in summer and fall. It was sparsely-distributed and therefore a very minor floral component. *Cladophora ruchingeri* has not been previously reported from the upper Texas Coast jetties. Lowe & Cox (1978) reported this species from Galveston, but only from inshore stations.

Cladophora vagabunda (Linnaeus) van den Hoek.—This species occurred as a minor floral component in the lower and middle zones at all stations, primarily during summer, and to a lesser extent in fall and winter. Lowe & Cox (1978) reported this species from the Galveston area but only from inshore stations.

Enteromorpha clathrata (Roth) Greville.—Although generally common throughout the year, this species was less prevalent in August. It was found throughout the intertidal zone at all stations. Lowe & Cox (1978) reported it as being dominant on the Galveston jetties in late winter and early spring. *Enteromorpha clathrata* was a minor floral component at Matagorda (Boyd & Wardle 1994) where it occurred during the winter in the lower intertidal zone.

Enteromorpha lingulata J. Agardh.—This species was a dominant floral component during winter and early spring and was commonly found throughout the remainder of the year at all three stations. It was most prevalent in the middle zone, although it was occasionally collected in the upper and lower zones as well. Lowe & Cox (1978) reported it as a dominant floral component in Galveston throughout the year; while Boyd & Wardle (1994) reported abundant populations of this alga during the winter from Matagorda.

Enteromorpha prolifera (O. F. Mueller) J. Agardh.—This species was common throughout the intertidal zone in winter and spring at all stations. Lowe & Cox (1978) reported this species at Galveston during winter months. Boyd & Wardle (1994) also reported its winter occurrence in the upper and middle intertidal zones at Matagorda.

Ulothrix flacca (Dillwyn) Thuret in Lew Jolis.—The inconspicuous, unbranched filaments of this species occurred as a very minor floral component in the middle zone of the channel station in summer and fall. Lowe & Cox (1978) recorded its prior occurrence from Freeport, but did not report it from the Galveston jetties. *Ulothrix flacca* has not been previously recorded from Matagorda.

Ulvella lens P. & H. Crouan.—This epiphytic species was found on *Cladophora dalmatica* in the middle zone in October at the channel station. Lowe & Cox (1978) reported its prior occurrence in Freeport, but did not record its presence at Galveston. *Ulvella lens* has not been previously reported from Matagorda.

Division Chrysophyta

Navicula sp.—This dendritic tube-dwelling diatom species resembles a small filamentous seaweed in size and growth habit. It was collected from all three intertidal zones at all stations in August and October as a minor floral component. It has not been previously reported from either Galveston or Matagorda.

Division Phaeophyta

Giffordia mitchelliae (Harvey) Hamel.—This species was collected in winter as a rare floral component of the lower and middle intertidal zones at the channel and tip stations. It has not been previously reported from either Galveston or Matagorda.

Giffordia rallsiae (Vickers) W. Taylor.—A minor floral component of the lower intertidal zone, this species was collected in summer, and to a lesser extent, in fall and winter at the channel and tip stations. It has not been previously reported from either Galveston or Matagorda.

Division Rhodophyta

Acrochaetium seriatum (Borgesen).—This epiphytic species was collected on *Cladophora dalmatica* and *Gelidium pusillum* in the middle and lower zones at the tip station in fall. *Acrochaetium seriatum* has not

been previously reported from the upper Texas Coast. Lowe & Cox (1978) reported another species of *Acrochaetium*, *A. flexuosum*, on *Cladophora dalmatica*, *C. montagneana* and *Bryocladia cuspidata* at Galveston. The patterns of lateral reproductive organs on specimens from Freeport found during the present study, however, differ from those of *A. flexuosum* and are more in agreement with those of *A. seriatum*.

Audouinella hoytii (Collins) Schneider.—This epiphyte was found on *Cladophora dalmatica* in the lower zone in August at the tip station. It has not been previously reported from either Galveston or Matagorda.

Bangia atropurpurea (Roth) C. Agardh.—This species was a minor floral component throughout the year, but was more abundant in the winter and early spring. It was collected from all stations and occurred in all three vertical zones, being more prevalent in the upper and middle. Lowe & Cox (1978) reported this species (as *B. fuscopurpurea*) from Galveston, and Boyd & Wardle (1994) reported it from Matagorda. Its pattern of seasonal and zonal occurrence in all three areas is similar.

Bryocladia cuspidata (J. Agardh) De Toni.—The distinctive radially-branched thalli of this species occurred as a rare floral component in the middle intertidal zone on the tip station in October. Lowe & Cox (1978) found this species to be a dominant floral component of the Galveston jetties in late summer and fall. *Bryocladia cuspidata* was sparsely represented on the Matagorda jetty during winter (Boyd & Wardle 1994).

Ceramium strictum (Harvey).—The low growing, densely aggregated thalli of this species were common in all vertical zones at all stations in the summer and fall, becoming less common during winter. The species was more abundant at the channel and tip stations than at the gulf station. Lowe & Cox (1978) reported it to be dominant in late summer and early fall in Galveston. *Ceramium strictum* has not been previously recorded from Matagorda.

Erythroceltis subintegra (Rosenvinge) Kornmann & Sahling.—This common epiphyte was collected on *Cladophora dalmatica*, *C. vagabunda*, *Gelidium pusillum*, *Polysiphonia boldii*, *Bangia atropurpurea*, *Bryopsis pennata* and *Enteromorpha lingulata* throughout the year. It was found in all three zones at all stations, but was less common in the upper zone. Lowe & Cox (1978) reported this species (as *Erythrocladia*

subintegra) as being common on the Galveston jetties during summer and fall. It has not been previously reported from Matagorda.

Erythrotrichia carnea (Dillwyn) J. Agardh.—This species was collected as an epiphyte on *Gelidium pusillum*, *Cladophora dalmatica*, *C. vagabunda*, *Polysiphonia boldii*, *P. tepida* and *Enteromorpha lingulata*. It was found throughout the year at all stations in all three intertidal subzones. This epiphyte was reported to be common in Galveston by Lowe & Cox (1978) in summer and fall. It has not been previously reported from Matagorda.

Gelidium pusillum (Stackhouse) Le Jolis.—This species was a minor floral component for most of the year, becoming more common in August. It occurred at all stations in the middle and lower zones, being more prevalent in the latter. This species was recorded at Galveston by Lowe & Cox (1978) throughout the year and was abundant from November to April. It has not been previously reported from Matagorda.

Polysiphonia boldii Wynne & Edwards.—This species was collected from all three intertidal subzones at the channel station in October, January and April, and from the upper zone at the gulf station in April. It was not observed during the warmer months (June and August). This species has not been previously recorded from either Galveston or Matagorda.

Polysiphonia tepida Hollenberg.—This rare floral component was collected from the lower zone at the gulf station in January. Lowe & Cox (1978) found it to be common on the south jetty at Galveston. It has not been previously reported from Matagorda.

Porphyra leucosticta Thuret in Le Jolis.—This species occurred as a minor floral component in the lower and middle zones at the channel and tip stations in January and April. Wardle (1992) found this species to be common on the Galveston jetties in late winter. It has not been previously reported from Matagorda.

Pterocladia bartletti W. Taylor.—This rare alga was collected from the upper zone at the gulf station in April. It has not been previously reported from either Galveston or Matagorda.

Stylocladia alsidii (Zanardini) Drew.—This species occurred as an epiphyte on *Cladophora dalmatica*, *Polysiphonia boldii*, and *Gelidium pusillum*. It was found each month throughout the intertidal zone at all

Table 2. Occurrence and distribution of intertidal macroalgal species from jetties of the upper Texas coast as reported by this and previous studies. See text and literature cited for full author citations.

	Galveston	Freeport	Matagorda
DIVISION CHLOROPHYTA			
<i>Bryopsis pennata</i>	Medlin	This report	-
<i>Chaetomorpha linum</i>	Lowe & Cox	Lowe & Cox, This report	Boyd & Wardle
<i>Cladophora dalmatica</i>	Lowe & Cox	Lowe & Cox, This report	Boyd & Wardle
<i>Cladophora montagneana</i> (also cited as <i>C. delicatula</i>)	Lowe & Cox	-	-
<i>Cladophora ruchingeri</i>	-	Lowe & Cox, This report	-
<i>Cladophora vagabunda</i>	-	Lowe & Cox, This report	-
<i>Enteromorpha clathrata</i>	Lowe & Cox	This report	Boyd & Wardle
<i>Enteromorpha flexuosa</i>	Lowe & Cox	-	-
<i>Enteromorpha lingulata</i>	Lowe & Cox	This report	Boyd & Wardle
<i>Enteromorpha prolifera</i>	Lowe & Cox	This report	Boyd & Wardle
<i>Ulothrix flacca</i>	-	This report	-
<i>Ulvella lens</i>	-	Lowe & Cox, This report	-
DIVISION CHRYSOPHYTA			
<i>Navicula</i> sp. (tubicolus)	-	This report	-
DIVISION PHAEOPHYTA			
<i>Giffordia mitchelliae</i>	-	This report	-
<i>Giffordia rallsiae</i>	-	This report	-
<i>Petalonia fascia</i>	Lowe & Cox	-	-
DIVISION RHODOPHYTA			
<i>Acrochaetium flexuosum</i>	Lowe & Cox	-	-
<i>Acrochaetium seriatum</i>	-	This report	-
<i>Audouinella hoytii</i>	-	This report	-
<i>Bangia atropurpurea</i> (also cited as <i>B. fuscopurpurea</i>)	Lowe & Cox	Lowe & Cox, This report	Boyd & Wardle
<i>Bryocladia cuspidata</i>	Lowe & Cox	Lowe & Cox, This report	Boyd & Wardle
<i>Ceramium strictum</i>	Lowe & Cox	Lowe & Cox, This report	-
<i>Erythrocptis subintegra</i> (also cited as <i>Erythrocladia subintegra</i>)	Lowe & Cox	Lowe & Cox, This report	-
<i>Erythrotrichia carnea</i>	Lowe & Cox	Lowe & Cox, This report	-
<i>Gracilaria foliifera</i>	-	Lowe & Cox	-
<i>Gelidium pusillum</i> (also cited as <i>G. crinale</i>)	Lowe & Cox	Lowe & Cox, This report	-
<i>Lomentaria baileyana</i>	-	-	Boyd & Wardle
<i>Polysiphonia boldii</i>	-	This report	-
<i>Polysiphonia denudata</i>	Lowe & Cox	Lowe & Cox	-
<i>Polysiphonia tepida</i>	Lowe & Cox	This report	-
<i>Porphyra leucosticta</i>	Wardle	This report	-
<i>Pterocladia bartlettii</i>	-	This report	-
<i>Stylonema alsidii</i> (also cited as <i>Goniotrichum alsidii</i>)	Lowe & Cox	Lowe & Cox, This report	-
Total Number of Species Reported:	20	28	8

Table 3. Salinity readings adjacent to the three sampling stations on the southwestern jetty at Freeport, Texas.

Sampling Date	Channel Station	Tip Station	Gulf Station
28 Jun. 1993	11 ppt	12 ppt	10 ppt
18 Oct. 1993	24 ppt	25 ppt	23 ppt
3 Jan. 1994	23 ppt	24 ppt	25 ppt
13 Apr. 1994	23 ppt	22 ppt	23 ppt
12 Aug. 1994	<u>30 ppt</u>	<u>30 ppt</u>	<u>31 ppt</u>
Station means:	22.2 ppt	22.6 ppt	22.4 ppt

stations. Lowe & Cox (1978) reported this species (as *Goniotrichum alsidii*) at Galveston during the summer and fall. It has not been previously reported from Matagorda.

DISCUSSION AND CONCLUSIONS

The results of this present study increases the number of rocky intertidal macroalgal species known to occur at Freeport from the 11 species reported by Lowe & Cox (1978) to 28. This is with the addition of eight chlorophytes, one chrysophyte (a macroscopic tubiculus diatom species), two phaeophytes and five rhodophytes (Table 1).

The Freeport flora is similar to that of the Galveston jetties which lie 70 km to the northeast, from which 16 of the 28 species recorded from Freeport have also been reported (Table 2). The Freeport and Galveston floras appear to be more diverse than that of Matagorda which lies 70 km to the southwest of Freeport. Only eight species have been recorded from Matagorda (Table 2), but due to the fact that the flora was sampled only in January, February and March by Boyd & Wardle (1994), it is quite possible that additional non-winter species may also occur there.

The results of the present study indicate that the Freeport jetty flora is dominated by *Cladophora dalmatica*, *Enteromorpha lingulata*, and *Gelidium pusillum* throughout the year. In winter, *Enteromorpha clathrata*, *Bangia atropurpurea*, *Porphyra leucosticta* and *Polysiphonia boldii* become prevalent as well, while in summer, *Cladophora vagabunda* becomes more abundant. The seasonal occurrence of algal types on the Freeport jetty thus differs somewhat from that of the Galveston jetties where Lowe & Cox (1978) reported more pronounced seasonal changes with distinctively different species groups dominant in summer and winter, with no single dominant species found throughout

the year. Noteworthy also is the paucity of *Bryocladia cuspidata* at Freeport, since this species is common at both Galveston to the northeast and Matagorda to the southwest (Lowe & Cox 1978; Boyd & Wardle 1994). Conversely, *Cladophora ruchingeri*, *Ulothrix flacca*, *Giffordia mitchelliae* and *G. rallsiae* were found with regularity at Freeport during the present study but have not been previously reported from either Galveston or Matagorda.

No significant differences in species composition among the channel, tip and gulf stations on the Freeport jetty were recognized. This may be attributed to the lack of significant differences in salinity among the three stations (Table 3).

The vertical intertidal zonation of the species found at Freeport during the present study is in general agreement with that observed for those species which also occur in other upper Texas Coast localities (Lowe & Cox 1978; Medlin 1984; Wardle 1992; Boyd & Wardle 1994). A notable exception, however, is the occurrence of *Gelidium pusillum* in both the middle and lower subzones of the intertidal zone at Freeport, since at Galveston this species appears to be restricted to the lower zone.

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IMMUNOLOGICAL RESIDUE ANALYSIS: RESULTS OF RECENT ARCHAEOLOGICAL AND EXPERIMENTAL STUDIES

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Abstract.—This study reports the results of immunological analysis of prehistoric materials recovered from archaeological sites located in far west Texas. This technique is used to identify plant and animal residues on ground and chipped stone artifacts and in sediments from hearths. This study demonstrates that positive results can be attained from a variety of archaeological materials in this application. Experimental blind-tests conducted in conjunction with the archaeological analysis suggest caution in the interpretation of immunological residue analysis.

Organic residues, which may include blood, fats and a wide variety of other plant and animal tissues, may be preserved on archaeological materials. Through the use of molecular biological techniques for the analysis of these residues, archaeologists may acquire direct data on plants and animals used in prehistoric subsistence (Briuer 1976; Shafer & Holloway 1979; Loy 1983; Lowenstein 1985; Hyland & Anderson 1990; Hyland et al. 1990; Cattaneo et al. 1991; Yohe et al. 1991; Newman et al. 1993). The application of these techniques is critical in areas such as west Texas where investigating prehistoric subsistence with traditional methods, such as macrobotanical or faunal analysis, is hampered by low rates of recovery.

This study reports the results of recent investigations of subsistence activities through immunological analysis of prehistoric artifacts and feature sediments from archaeological sites in far west Texas. The archaeological materials are from sites located in the Hueco Bolson, an intermontane lowland in the Chihuahuan Desert extending from south-central New Mexico through west Texas and into northern Mexico (Figure 1). The archaeological samples analyzed were recovered from excavated sites located on Fort Bliss Military Reservation (Scarborough 1989; Leach 1994; Mauldin et al. 1994). Based on radiocarbon dates recovered from features, the samples span a period from about 2500 B.C. to A.D. 1300, with the exception of a single Folsom projectile point, that probably is 9-10,000 years old. A total of 202 archaeological samples were submitted for cross-over immunoelectrophoresis (CIEP), an immunological technique originally developed in medico-legal work (Culliford 1964; Gaenslen 1983; Newman & Julig 1989). The archaeo-



Figure 1. Map of study area.

logical samples included ground and chipped stone tools and ceramics. Sediment and fire-cracked rock from prehistoric hearths were also submitted. Positive results were obtained on 37 of these samples. A variety of expected subsistence resources were identified. The technique also indicates the use of some form of felid (e.g., bobcat, mountain lion) and canid (coyote, dog, fox). These two groups have not been documented as subsistence items by previous research in the region.

The reliability of the technique is assessed through experimental blind-tests. Specifically, 16 modern chipped stone artifacts were submitted for CIEP analysis that were used to process known animals and plants. Though conducted on a limited number of plants and animals, the results of these blind-tests tentatively support the archaeological identifications. However, several of the identifications are problematic, suggesting caution in the interpretation of the archaeological results.

A variety of sediment samples from the study area were submitted to control for possible contamination. Naturally occurring contaminants

(bacteria and chemicals such as aluminum chromate and manganese oxide) in site sediments may result in false-positive reactions in tests (Culliford 1964; Custer et al. 1988). Sediments adhering to artifacts may produce reactions that could be interpreted as prehistoric residue (Newman et al. 1993). The sediment samples submitted as controls in this study tested negative. In this case sediment contaminates do not appear to cause false-positive reactions. While problems with the period of time over which residues retain their biological activity still need to be considered (Child & Pollard 1992; Cattaneo et al., 1993; Eisele, 1994), the results of both the control samples and experimental samples suggest that the use of immunological techniques provide an additional means to investigate prehistoric subsistence in the region.

METHODS

Numerous immunological techniques have been used to identify organic residues from archeological materials (Loy 1983; 1993; Lowenstein 1985; Newman & Julig 1989; Cattaneo et al. 1990; Hyland et al. 1990; Downs 1993). All rely on the observation that mammals have well developed immune systems that produce antibodies to foreign substances (antigens) as part of the body's defense system.

Cross-over immunoelectrophoresis is the immunological method used in this analysis (Newman & Julig 1989). As with all immunological techniques, CIEP requires (1) the production and isolation of antibodies (antisera) to known plants and animals, (2) the removal and isolation of plant or animal residue from artifacts or sediment, (3) the exposure of the plant or animal residue to a series of antisera, and (4) methods for observing the strength of the reaction of the antisera to the unknown residue. For the purposes of archaeological research, where organic preservation is limited, the CIEP test is ideal in that as little as 10^{-8} g of protein can be detected by the technique (Culliford 1964:120).

To generate antibodies needed for immunological analysis, a host animal (e.g., a rabbit) is injected with the serum of the species (e.g., deer, corn) that one wishes to detect. When a suitable time after injection has passed for the host animal to generate antibodies (2-3 months), blood is withdrawn from the host and the red blood cells are removed leaving only the antisera. The antisera contains proteins from the host animal and antibodies generated in the host (Culliford 1964; Roitt et al. 1985; Child & Pollard 1992; Eisele 1994).

Following the removal of the unknown residues (antigen) from the archaeological material, the antigen is exposed to a variety of known antiserum. The antiserum will bind to the protein molecule against which it was raised, forming an extended lattice (Benjamin et al. 1984; Newman & Julig 1989; Child & Pollard 1992).

The antibodies used in this analysis are polyclonal. That is, they may recognize other species within a family, and occasionally may cross-react beyond the family level. For example, positive reaction to deer antiserum may occur with any member of the family Cervidae. This is a result of the host animal producing multiple antibodies that can bind to different antigenic sites on the foreign substance (Child & Pollard 1992; Eisele 1994). When antibodies developed in a host animal are brought in contact with an unrelated antigen, they may align differently on an antigenic site (Abbas et al. 1991). This phenomenon is referred to as "multispecificity" (Guttman 1989; Newman & Julig 1989). However, the primary reaction of a polyclonal antiserum will be with the whole antigen against which it was raised (Culliford 1964).

ARCHAEOLOGICAL RESULTS

A total of 131 chipped stone tools (projectile points, utilized flakes, bifacial and unifacial items), 33 ground stone tools (manos and metates), four fire-cracked rock samples (5-10 rocks in each sample), one ceramic sample (four sherds), and 33 sediment samples (80-100 ml each) were submitted for CIEP analysis. The archaeological samples were tested against a series of antiserum, including those developed for bear, bovine, cat, chicken, deer, dog, elk, guinea-pig, human, pronghorn, rabbit, rat, sheep, turkey, acorn, corn, mesquite, and yucca.

Of the 202 archaeological samples submitted, 37 (18%) produced a reaction with at least one antiserum (Table 1). Seven sediment samples, four ground stone artifacts, and two chipped stone tools tested positive for rabbit antiserum. This reaction may be associated with any member of the family Leporidae. One specimen (FB12547-1027) that tested positive for the rabbit antiserum also gave a weaker reaction to deer antiserum. Positive results to deer antiserum, indicative of members of the family Cervidae, were obtained on five chipped stone tools. Positive results to cat (Felidae) antiserum were noted on a single mano. A total of three chipped stone tools tested positive to dog (Canidae) antiserum and three to guinea-pig (Caviidae). Previous studies (Newman & Julig 1989) have demonstrated that guinea-pig antiserum can react to other members within the order Rodentia, with strong reactions to porcupine

Table 1. Positive reactions from 37 of the 202 archaeological samples tested.

Site* and Catalog Number	Sample Type	Reaction
FB13204-165	Sediment	Rabbit
FB13167-185	Sediment	Rabbit
FB13167-186	Sediment	Rabbit
FB13178-51	Sediment	Rabbit
FB12830-163	Sediment	Rabbit
FB12719-2281	Sediment	Rabbit
FB12761-118	Sediment	Rabbit
FB12900-345	Sediment	Mesquite
FB12650-1027	Mano/Metate	Rabbit
FB12648-2004	Mano	Rabbit
FB13259-10	Metate	Rabbit
FB12709-33	Mano	Rabbit
FB12657-4	Mano	Cat
FB12748-42	Mano	Corn
FB6281-1096	Mano	Corn
FB 6281-87	Mano	Corn
IF 8828-48	Mano	Mesquite
IF12649-2487	Mano	Yucca
FB 6741-320	Lithic tool	Rabbit
FB12547-439	Lithic tool	Rabbit, Deer
FB13192-4	Lithic tool	Deer
FB 6741-77	Lithic tool	Deer
FB 6741-996	Lithic tool	Deer
FB 7510-525	Lithic tool	Deer
FB 7510-475	Lithic tool	Deer
FB 7843-103	Lithic tool	Human
FB 7484-249	Lithic tool	Dog
FB 7510-203	Lithic tool	Dog
FB12229-535	Lithic tool	Dog
FB12254-24	Lithic tool	Rat
FB 7510-658	Lithic tool	Mouse
FB 6281-388	Lithic tool	Chicken
FB 7510-577	Lithic tool	Guinea-pig
FB 7520-382	Lithic tool	Guinea-pig
FB10407-7	Lithic tool	Guinea-pig
FB 6281-2134	Lithic tool	Yucca
FB 6281-2133	Lithic tool	Mesquite

* The site number is specific to Fort Bliss. Corresponding Texas Trinomial numbers can be acquired from the Archaeology Branch, Directorate of Environment, Fort Bliss, Texas.

(Erethizontidae). Positive reactions to human (Hominidae), mouse and rat (prob. Heteromyidae), and chicken (*Gallus*) were also obtained on chipped stone tools. The chicken may indicate any avian.

Plant residues were noted on six of the 37 artifacts that tested positive. Positive results to corn (Gramineae) were obtained on three manos. Yucca (Lilaceae) was detected on one mano and one chipped stone tool, and a reaction to mesquite (Fabaceae) was present on one chipped stone tool.

Table 2. Results of experimental blind-tested samples.

Artifact Type	Experimental Residue	Results
Lithic tool*	Rabbit	Negative
Lithic tool	Rabbit	Rabbit
Lithic tool	Rabbit	Rabbit
Lithic tool	Rabbit	Rabbit
Lithic tool	Rabbit	Rabbit, mouse
Lithic tool	Rabbit	Turkey
Lithic tool	Rabbit	Rabbit
Lithic tool	Lechuguilla	Negative
Lithic tool	Lechuguilla	Negative
Lithic tool	Prickly pear	Negative
Lithic tool	Prickly pear	Negative

* = Sample was baked in a oven at 250°C for 30 minutes.

No residues were detected on the remaining 165 samples. The absence of identifiable proteins may be attributed to a variety of processes. The dearth of reactions may be related to poor preservation of protein (Benjamin et al. 1984; Child & Pollard 1992), a lack of conformational integrity between the antiserum and the antigen being tested (Benjamin et al. 1984), or that the materials were exposed to species not encompassed by the antiserum. Finally, the archaeological materials may never have been in contact with any plant or animal. The lack of positive reactions from fire-cracked rock samples may be a function of the high temperatures (Cattaneo et al. 1994) associated with prehistoric hearths. However, the identification of residues from hearth sediments makes this premise less likely.

EXPERIMENTAL ANALYSES AND RESULTS

The experimental portion of this study was undertaken as a contribution to the continued debate about the capability of immunological and other blood identification techniques to correctly identify prehistoric residues (Gurfinkel & Franklin 1988; Smith & Wilson 1992; Eisele 1994; Manning 1994). The experiment concentrated on the identification of known sources, such as rabbit, and the potential for cross-reactivity using experimental plant antigens that were not present in the antiserum used for the testing.

A total of 16 chipped stone artifacts with known residues were submitted along with the archaeological specimens for analysis. Twelve artifacts were coated with blood from a jackrabbit (*Lepus californicus*), two were used to process lechuguilla (*Agave lecheguilla*), and two were used on prickly pear (*Opuntia* sp.). The tools used in the experiment were produced by the authors. After treatment, each of the experimental artifacts was allowed to dry, wiped with a cotton cloth and rubbed lightly with sand to remove obvious residues. Experimental samples were tested against the same range of antiserum used in the analysis of the archaeological specimens. The results of this blind-test are presented in Table 2.

Of the 12 experimental artifacts coated with rabbit blood, nine were correctly identified. One was correctly identified, but also elicited a cross-reaction to mouse antiserum. One specimen was incorrectly identified as turkey. In addition, one specimen that had been heated in a conventional oven for 30 minutes at 250°C, tested negative. The four specimens used to process the plant material did not react to any antiserum.

These experimental results are encouraging in light of others recently conducted which suggest that proteins undergo rapid degradation (Gurfinkel & Franklin 1988; Hyland et al. 1990; Eisele 1994). While the time period between coating of artifacts with experimental residue and the analysis of those artifacts was, in all cases, less than two months, degradation of proteins does not appear to be significant in our experimental samples. Rabbit blood is consistently identified with two exceptions. First, an artifact produced a cross-reaction to mouse antisera. Secondly, a single specimen was mis-identified as turkey. These two types of cross-reactions accentuate a critical concern in that an immunological reaction between chemically and structurally dissimilar antiserum and antigen can occur (Gaensslen 1983).

The negative result obtained from the specimen that was heated is consistent with previous thermal experiments. For example, Cattaneo et al. (1994) reported that although human albumin maintained biogenic activity for 1 hour at 100°C and for at least 10 minutes at 300°C "antigenicity was lost between 300-350°C". The lack of cross-reactions of the two experimental plant antigens with other plant antiserum is promising. Most importantly, no cross-reaction between plants and animals occurred.

CONCLUSIONS

This study confirms the presence of plant and animal residue on ground and chipped stone artifacts and on sediment from hearths, suggesting that protein residues may survive in sufficient quantities in their biologically active form to be detected immunologically. The successful identification of the antigen of origin in most cases in the experimental samples lends support to these conclusions. However, the technique failed to correctly identify one animal, and the cross-reaction of a second specimen suggests that archaeological results be interpreted with caution. Recent work by Cattaneo et al. (1993) and Eisele (1994) suggest that the application of immunological techniques to archaeological specimens may be problematic. These two studies imply that experimental artifacts, coated with known blood and buried for relatively short time periods, may lose their biological identity. As such, the results obtained by immunological technique on archaeological material, in settings where proteins may have undergone degradation, may produce spurious results. Nevertheless, while further archaeological and experimental immunological studies must be conducted, results of this study in which plant and animal residues are identified on a variety of archaeological materials, may provide an additional source of information on prehistoric subsistence behavior.

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FINE-SCALE SPATIAL VARIATION OF SEDIMENT COMPOSITION AND SALINITY IN NUECES BAY OF SOUTH TEXAS

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Abstract.—A thorough investigation of the sediment texture and salinity regime was conducted during August of 1993 at 101 stations within Nueces Bay, Texas. Based on these results, the bay can be divided into four salinity regions, with three sediment types. The four salinity regions at this time included: a low salinity region (13.3-20.5 ppt), a mid salinity region (20.5-26.1 ppt), a high salinity region (26.1-30.6 ppt), and an elevated region (26.1-30.6 ppt) where the salinity is influenced by cooling water discharges from the Central Power and Light plant. The three sediment types include: muddy sediments (<50% sand), muddy-sands (50-75% sand), and sandy sediments (>75% sand). Muddy-sands predominate with sandy sediments prominent along the northern and southern shores. Muddy patches are distributed in the mid-section, eastern and western edges of the bay. A comparison of changes in sediment composition which have occurred in Nueces Bay since the completion of the Choke Canyon dam-reservoir in 1982 is reviewed. Nueces Bay is physically and chemically variable on fine spatial scales (500 m to 1 km).

Sediment composition and salinity distribution are important descriptors of physical conditions within estuaries. Wind stress, tidal flow, Coriolis effect, bathymetry, climate and river flow determine salinity structure (Bowden 1967). Salinity distributions provide evidence of mixing and circulation patterns (Postma 1967; Dyer 1979). Fluctuations in freshwater inflow caused by dams, water diversions, and climatic events can have major effects on the environmental conditions and ecological nature of estuaries such as Nueces Bay. Subsequently, estuarine circulation is important in determining sediment transport and distribution (Dyer 1979). Sediment and salinity play critical roles in the ecology, chemistry and physical characteristics of estuaries (Kennish 1986). Thus, the evaluation of sediment and salinity regimes is essential in planning estuarine studies.

Nueces Bay is a secondary bay, located in the semi-arid climatic zone of Texas, receiving 70 cm yr⁻¹ of precipitation with an evaporation rate of 152 cm yr⁻¹ (Henley & Rauschuber 1981). Climatic variation such as floods, droughts and intermediate levels of rainfall, affect the level of

freshwater inflow that ultimately determines salinity distribution within Nueces Bay (Brown et al. 1976). Two dams restrict the flow of the Nueces River. Wesley Seale Dam (64.4 km of river within reservoir) was constructed between 1956-1958, and Choke Canyon Dam (54.7 km of river within reservoir) was constructed from 1978-1982 (Henley & Rauschuber 1981; Corpus Christi Wastewater Division Pers. comm.). Corpus Christi Water Division data indicate that Nueces Bay receives $2.24 \times 10^8 \text{ m}^3 \text{ yr}^{-1}$ (1978-1993 yearly mean) of freshwater inflow (Freund & Nicolau 1994). A U.S. Bureau of Reclamation Environmental Impact Statement reported that the Nueces river basin contributed $6.35 \times 10^8 \text{ m}^3 \text{ yr}^{-1}$ of freshwater inflow into Nueces Bay, yearly average from 1941-1965, prior to Choke Canyon construction (U.S. Department of Interior 1975; Henley & Rauschuber 1981). After construction of the Choke Canyon Dam and reservoir, freshwater inflow into Nueces Bay in the year 2010 was predicted to be $2.6 \times 10^8 \text{ m}^3 \text{ yr}^{-1}$ (U.S. Department of the Interior 1975; Henley & Rauschuber 1981). A Texas Department of Water Resources (TDWR) report based on data from 1941-1975 predicted $3.53 \times 10^8 \text{ m}^3 \text{ yr}^{-1}$ of freshwater inflow into Nueces Bay in 2010 (Henley & Rauschuber 1981). The TDWR estimated that operation of the Choke Canyon reservoir would increase salinity in areas of Nueces and Corpus Christi Bays due to lower freshwater inflow (Henley & Rauschuber 1981). The salinity predictions at the Nueces River mouth were an 82% frequency of $>35 \text{ ppt}$ as opposed to 71% without the Choke Canyon reservoir and also lower frequencies for all lower salinity ranges (Henley & Rauschuber 1981).

River flow is the principal means of sediment transport into estuaries (Kennish 1986). Nueces Bay receives most of its sediment from the Nueces River (TDWR 1981). However, dams and water diversions restrict water flow and thus sediment load into the bay, altering the natural state of the system. Restriction in riverine sediment load into Nueces Bay indicates that other sources of sediments, such as erosion of the surrounding shoreline, are increasingly important (TDWR 1981). However, during flood events, the Nueces River can transport large amounts of sediment into Nueces Bay (TDWR 1981). Sediments near the Nueces River mouth as well as the region next to the Nueces Delta contain greater amounts of clays and silts because of low river inflow (TDWR 1981). The area surrounding Nueces Bay consists of Pleistocene Beaumont Clay (TDWR 1981). However, sandy soils along the northern and southern coasts of the bay suggest that surface sediments are predominantly sandy along the northern and southern shores and less sandy towards the center of the bay (Brown et al. 1976). Drought and

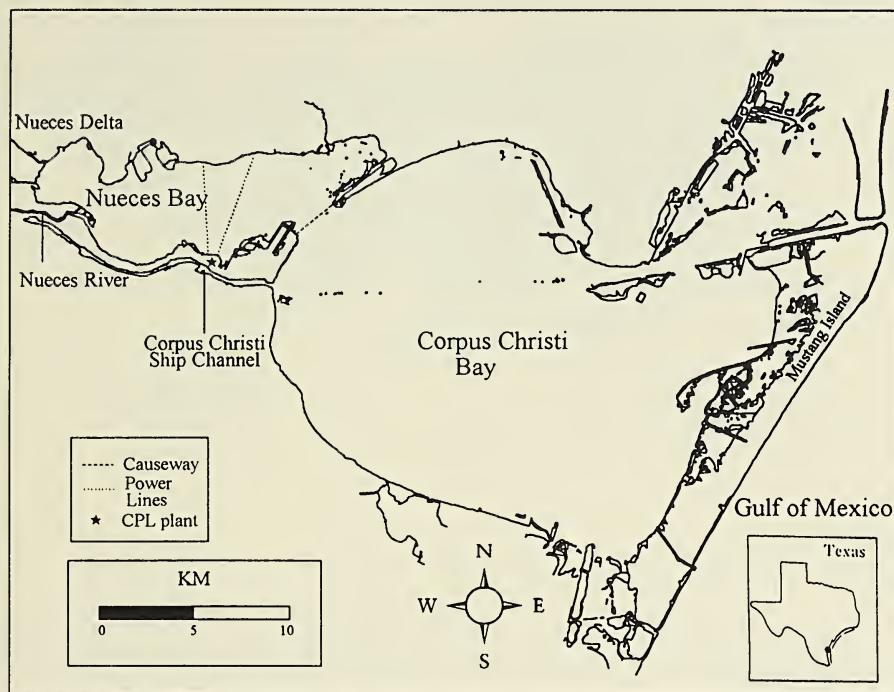


Figure 1. Study area: map includes most of the Nueces Estuary (scale 1:300,000). Inset shows location of the estuary. Digitized hydrographic data from USFWS (1979).

flood events dominate the resulting sediment and salinity structure of Nueces Bay because of lower freshwater inflow caused by water diversions.

Fine-scale sediment and salinity distributions are necessary to permit broader scale measurements of biota, while maintaining a high degree of spatial resolution. Moreover, patchiness in sediment and salinity may be missed at coarser scales. To achieve a high resolution, 101 random stations (500 m to 1 km apart) were sampled throughout the bay. Sediment types were classified according to the percentage of sand, silt and clay fractions. A Geographic Information System (GIS), using Atlas GIS software, was the technique used to analyze the spatial variation of sediment composition, salinity and depth measurements throughout the bay.

METHODS

Nueces Bay is approximately 81 km², located on the Texas coast at 27° 50'-52' N latitude and 97° 30'-50' W longitude (Figure 1; USFWS

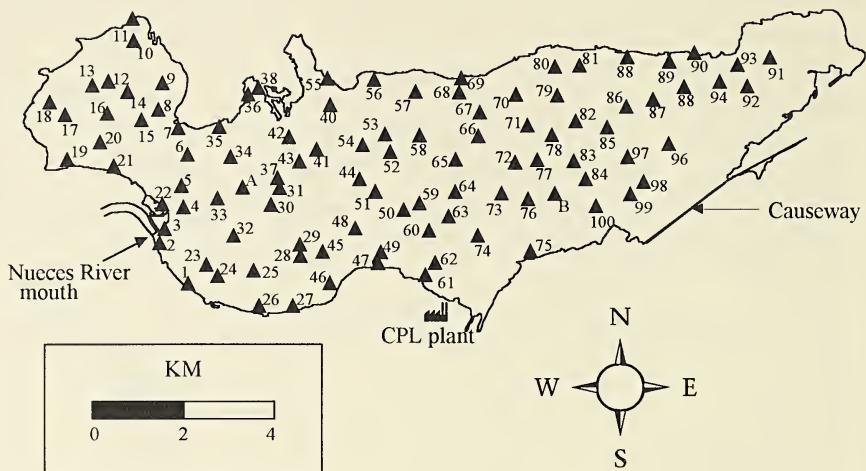


Figure 2. Location of stations in Nueces Bay.

1979). In August of 1993, sediment samples and hydrographic data were collected at 101 randomly selected stations throughout Nueces Bay (Figure 2). A grid with cartesian coordinates was placed over a map of Nueces Bay to select station locations using random number tables. Each station was located with a Trimble, Transpak II GPS (Global Positioning System) unit with at least 100 m accuracy. Surface and bottom water salinity, temperature, conductivity and depth were measured using the Hydrolab 4000. One sediment sample per station was collected with 6.7 cm diameter tube cores either remotely or by snorkeling, depending on the depth and substrate (Montagna & Kalke 1992). Cores were subdivided into a surface layer (0-3 cm) and placed in a Whirl-Pak.

Sediment composition (content of sand, silt and clay) and particle size are measured by standard techniques, wet sieving and pipette analysis (Folk 1964). Sediment samples are homogenized and a subsample of 20 cm³ is placed in a beaker with 50 ml of 3% hydrogen peroxide and 75 ml deionized water to dissolve organic material within the sediment. After three to four days, the hydrogen peroxide solution is drained. The sand and coarser fraction are separated from silt and clay particles by wet sieving through a 62.5 µm screen with a vacuum pump. The sand-gravel fraction is dried for 24 hours at 100 °C and then weighed after sediment reaches room temperature (minimum of 2 hours after oven removal). The sand fraction is further subdivided with a Ro-Tap device

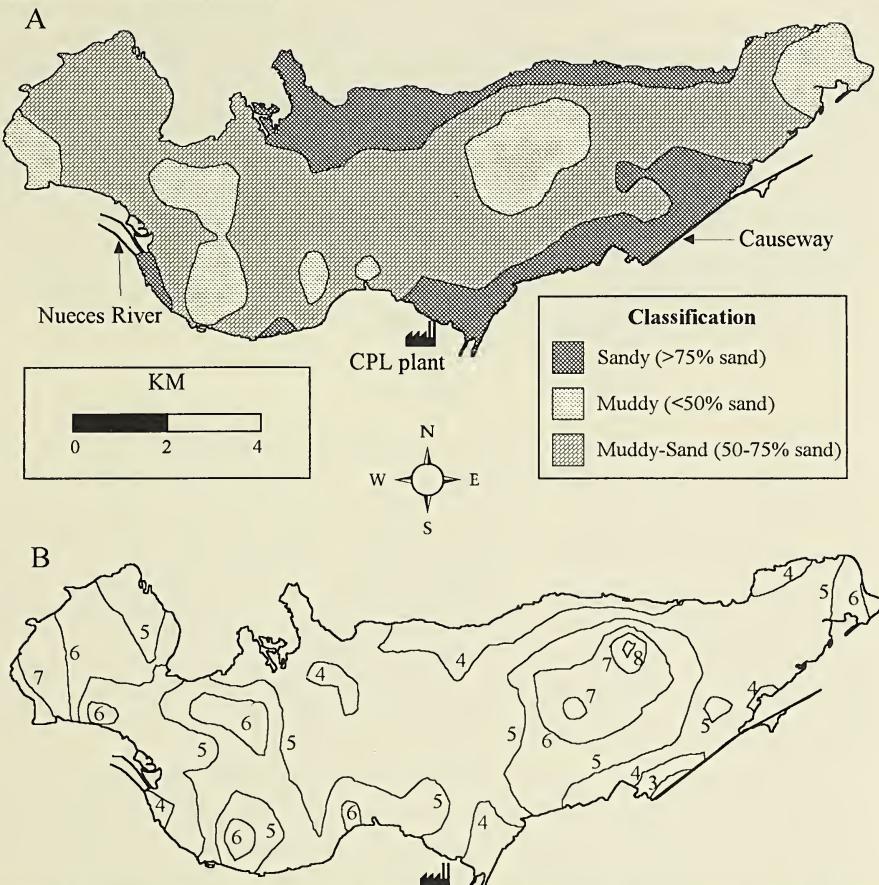


Figure 3. (A) Nueces Bay sediment composition. (B) Isopleths of sediment mean phi size.

and a series of sieves, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and a bottom pan ($<0.125\text{mm}$ and $>0.0625\text{mm}$) to separate out the gravel, very coarse sand, coarse sand, medium sand, fine sand and very fine sand, respectively (Ingram 1971). Fine particles are separated through pipette analysis described by Galehouse (1971) into three size fractions, coarse silt, fine silt and clay (Buchanan & Kain 1971). Sediment size is calculated as phi units, $-\log_2$ of grain diameter in mm, from the weights of each sediment fraction (McBride 1971). Sediments are classified with the triangular classification system, according to the percentage of each sediment fraction (sand, silt, clay; Buchanan & Kain 1971).

SYSTAT software is used to calculate contours from sediment composition, salinity, and depth data, using negative exponentially weighted smoothing (NEXPO). The NEXPO procedure fits a curve

through a set of points whereby the influence of neighboring points decreases exponentially with distance (McLain 1974; SYSTAT 1992). This smoothing algorithm is similar to the distance weighted least squares regression smoothing (SYSTAT 1992). The contours from SYSTAT are then digitized into the Geographic Information System software (Atlas-GIS for DOS 1992) for analysis and presentation (Atlas-GIS for Windows 1993). GIS integrates several types of data, such as sediment composition, salinity, depth, etc., with computerized maps at the proper latitude-longitude coordinates.

RESULTS

Nueces Bay sediments consist primarily of fine sands with several mud patches distributed throughout the bay (Fig. 3A). The sediment distribution map shows that the northern and southern shores contain primarily sandy sediments (> 75% sand). Muddy-sands (50-75% sand) predominate through most of Nueces Bay. Muddy sediments (< 50% sand) are concentrated in small patches near the present river mouth, adjacent to the old river mouth by the Nueces Delta, at the center of the bay, and next to a small creek delta on the eastern corner of the bay. Unexpectedly, sandy sediments were found at the Nueces River mouth.

Distributions of sediment phi sizes also show that Nueces Bay contains fine sands (Figure 3B). Generally, the distribution of mud patches and sandy sediments is indicated by high and low phi values, respectively (ranging from 2.26 to 8.71 phi). Phi values of < 5 represent sediments with high sand content and phi values > 5 are indicative of fine sediments.

Nueces Bay is shallow. The greatest depth measured in August of 1993 was 1.5 m at station 98 (Figure 4). Of course, meteorological factors such as floods, droughts, spring tides, wind stress, etc. can elevate or depress the water level. In any event, a representation of the bathymetry shows the relative depths from one area of the bay to another. The mid-section of the bay and the area near the causeway have the greatest depth, ranging from 1 m to 1.5 m, but predominantly 1 to 1.25 m (Figure 4). The shallow areas are located along the shore and next to the Nueces Delta and the Nueces River mouth.

The salinity distribution throughout the bay provides evidence of the circulation pattern and physical structure of Nueces Bay (Figure 5). The influences of freshwater inflow from the river and saline water from

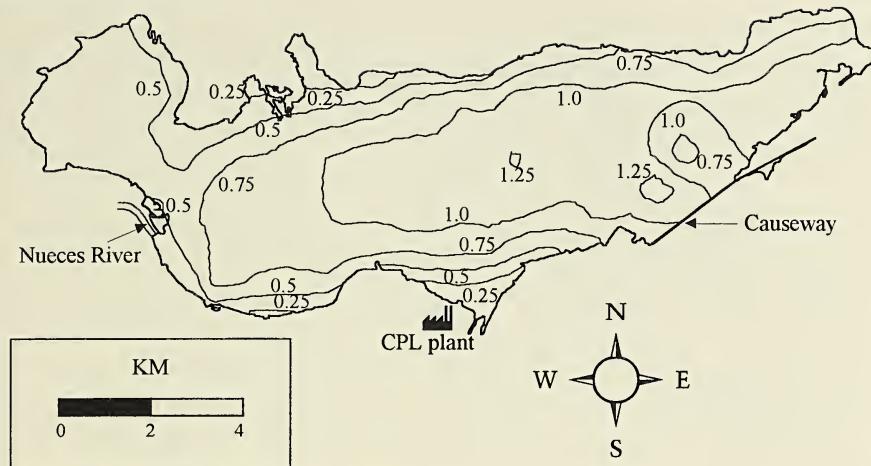


Figure 4. Nueces Bay bathymetry (meters).

Corpus Christi Bay entering through the causeway are quite evident from the isohalines. In addition, a plume of highly saline water is discernible along the central southern shore. This plume is caused by the daily discharge of approximately $1.4 \times 10^6 \text{ m}^3 \text{ day}^{-1}$ of cooling water from the CPL power plant located on the southern shore (Whitledge 1993). CPL pumps seawater at a depth of 5 m from the Corpus Christi ship channel located directly south of Nueces Bay (Fig. 1). The seawater is heated within the power plant and discharged directly into Nueces Bay. Therefore, warm saline water is released into the bay affecting the physical and chemical nature of that region. An area of homogeneous salinity is evident through much of the northern mid-section of the bay. Thus, the bay can be divided into four sections corresponding to the salinity structure, i.e. the freshwater influence zone, a CPL zone, a marine zone next to the causeway, and the homogeneous mid-section.

DISCUSSION

Fine sands are the major constituents of surface sediments in Nueces Bay. Sediments with the highest sand content are found at the river mouth and along the northern and southern shores; however, muddy-sands predominate throughout the bay (Figure 3A). Muddy sediments occur in several patches near the river mouth, mid-section, and northeastern section of the bay.

In 1979, the Bureau of Economic Geology (BEG) conducted an extensive study of sediment composition, bathymetry and salinity in Nueces Bay as part of the Submerged Lands of Texas series (White et

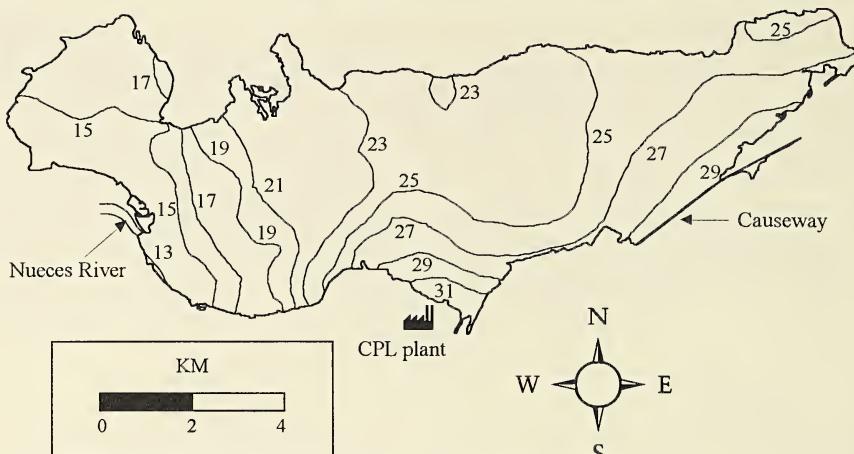


Figure 5. Bottom salinity isopleths (ppt) (August, 1993).

al. 1983). The BEG study showed that much of the bay is dominated by clayey silt (50-75% silt) and sand-silt-clay sediments (<50% sand, silt, and clay; White et al. 1983). The clayey silt and sand-silt-clay size classifications are equivalent to the muddy sediment classification used in this study (Figure 3A). In 1979, sand dominated areas were confined to the northern shore, next to the Nueces Delta, and the area adjacent to the causeway (White et al. 1983). Also, sediments with >75% sand were limited to a thin section along a small area of the northern shore (White et al. 1983). In contrast, in 1993, Nueces Bay sediments consisted primarily of fine sands with muddy-sands (50-75% sand) dominating through much of the bay (Fig. 3A). Furthermore, large areas along the northern and southern shores contained sandy sediments (>75% sand), with muddy sediments (<50% sand) confined to small patches near the present river mouth, adjacent to the old river mouth by the Nueces Delta, at the center of the bay, and next to a small creek delta on the eastern corner of the bay.

There are at least six possible explanations for the differences between the studies. One possibility is the effects of the Choke Canyon Dam, completed in 1982 after the BEG study, restricting river flow and subsequently the nature and quantity of sediment load entering Nueces Bay. The reservoir functions as a settling basin, reducing total sediment discharge by entrapment. Furthermore, coarser sediments settle to the bottom faster; thus, the remaining discharge contains muddier sediments.

Secondly, climatic events over the 14 year period between the two studies could also modify sediment composition. This is likely due to the tremendous sediment load during flood events. Although flood

events are infrequent, several flood events occurred between 1978-1993 (Freund & Nicolau 1994). After the 1992 flood event, over 20-30 cm of newly deposited fine sediment was observed on the Nueces Delta (Whitledge Pers. Comm.), suggesting that finer sediments should predominate through much of the mid-section of the bay.

A third explanation involves differences in sampling techniques. In the BEG study, a Ponar clam-shell grab sampler was used to collect sediments, destroying vertical stratification, and subsampled without homogenization for quantitative analysis. In contrast, sediment tube cores were collected to maintain vertical structure and sectioned to a depth of 3 cm in the current study. The entire sample was homogenized and then subsampled for quantitative analysis as described previously.

A fourth possible explanation entails differences in sediment analysis. In the BEG study, sands were analyzed with a rapid sediment analyzer and fine sediments were quantified with a Coulter Counter (White et al. 1983). However, the Coulter Counter technique may neglect a significant quantity of clay (Behrens 1978). Therefore, it is doubtful that this could account for the observed differences.

Furthermore, this current study employed finer spatial scales for Nueces Bay, since sediments were collected at 101 stations as opposed to 33 stations in the BEG study. For example, in the BEG study, several sediment classifications were each represented by a single station.

Finally, the present sediment distribution maps (Fig. 3) are based on regression-like calculations as opposed to subjective observations based on limited data. Of these six possibilities, spatial and temporal scale (influence from both the Choke Canyon Dam-reservoir and climatic events) effects are the most likely to account for the differences found. In the current study, coarser sediments were found, as indicated by the extensive areas of muddy-sands and only a few patches of muddy sediments. In contrast, the BEG study found primarily muddy sediments (White et al. 1983).

The Nueces River is generally characterized as a low flow river because of the climatic region, dams and diversions of water. Besides restricting freshwater inflow, dams restrict riverine sediment load into Nueces Bay, especially the coarser sediments, which require a higher transport velocity than silts and clays. In arid regions, rates of sediment accumulation may be lower, and wind increases in importance for sediment transport (Rusnak 1967). TDWR suggests that energy levels

required for erosion of sediments is dominated by winds and wind-generated waves in Nueces Bay because tidal range is low, 0.15 m (TDWR 1981). Other sources of sediments such as from the erosion of the surrounding shoreline are increasingly important. Observations made during the course of this study support the hypothesis that the land surrounding the shore is a possible source of sediments for Nueces Bay (Brown 1976). Much of the northern shore is composed of cliff-like dunes of sand with little vegetation. The appearance of these features suggests that slumping occurs (TDWR 1981). Higher stability is evident along the southern shore which contains primarily sands with a moderately sloped face. Sediment composition along the shores of the Nueces Delta, the northwest corner of the bay, and the northeast corner (which is adjacent to a small delta) contain higher amounts of muddy sediments similar to the surrounding marsh. However, during flood events, the Nueces River can transport large amounts of sediment into Nueces Bay (TDWR 1981). Riverine sediment load during a flood consists predominantly of fine sediments once it reaches the mouth of Nueces Bay.

Another effect of decreased sediment discharge into the bay is the coarsening of sediments already present within the bay by wave winnowing (Behrens Pers. Comm.). Wave winnowing is the resuspension of sediment particles by waves and currents; coarser sediments remain on the bottom as finer particles are resuspended and transported. Therefore, extreme climatic events such as droughts, floods and hurricanes may control the sediment structure of Nueces Bay because of low river flow caused by water diversions.

A consequence of the shallowness of Nueces Bay is the effect of wind and waves on sediment distribution, the physical/chemical structure, and subsequent effects on the biota. The depth through most of the bay is < 1.25 m indicating a tight benthic-pelagic coupling (Figure 4).

The isohalines indicate that salinity is influenced by several factors that are spatially isolated. Lower salinity in the region next to the river mouth shows that freshwater inflow does influence the bay (Figure 5). Although the causeway stretching across the mouth of the bay alters the flow between Nueces Bay and Corpus Christi Bay, the isohalines show that higher salinity water enters from Corpus Christi Bay. The salinity measurements are important in illustrating the potential influence that the CPL discharges have on the ecology of Nueces Bay. Whittlesey (1993) demonstrated that the salinity influence from the discharge varies seasonally and annually. However, the extent of the CPL influence is

limited to a small area (Whitledge 1993). The mid-section of the bay is homogeneous in terms of salinity and may also be similar biologically.

Freshwater inflow not only influences sediment and salinity, but it is also a source of nutrients (TDWR 1981; Kennish 1986). Nutrients are utilized for primary production, providing food for various organisms within the estuary, including recreational and commercial species (TDWR 1981).

CONCLUSIONS

Nueces Bay is highly variable spatially as shown by the salinity, sediment composition and depth data. Several events can influence these three factors such as climate, astronomical cycles, or anthropogenic modifications of the natural state of the system. Nueces Bay can be divided into four regions corresponding to the salinity structure, a freshwater influence zone, a CPL zone, a marine zone next to the causeway, and the homogeneous mid-section. Furthermore, the three sediment types sufficiently represent the sediment composition of Nueces Bay. GIS techniques combined with statistical software provide the capability for complex analysis and presentation of a myriad of spatial data. Construction of the Choke Canyon Dam-reservoir system has caused the coarsening of sediments within Nueces Bay. Clearly, restrictions of freshwater inflow influence the physical, chemical and ecological nature of the estuary. Temporal studies are needed to ascertain the full impact of climate and anthropogenic effects on the physical/chemical structure of estuaries that affect and perhaps regulate biotic community structure.

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ONTOGENETIC VARIATION IN THE DIET OF THE
SOUTHERN COPPERHEAD, *AGKISTRODON CONTORTRIX*,
IN NORTHEASTERN TEXAS

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Abstract.—The stomach contents of a series of 96 specimens of *Agkistrodon contortrix* from two adjoining counties in northeastern Texas were examined. Arthropods comprised the majority of prey items (53%) but lizards, snakes and a few rodents were also consumed by southern copperheads. Neonate and small copperheads (less than 35 cm SVL) were found to contain more squamata, whereas midsize (35 to 45 cm SVL) and adult snakes (greater than 45 cm SVL) were found to contain primarily cicadas and lepidopteran larva. Only adult specimens were found to contain rodents as prey items. The small gape of neonate and young copperheads appears to restrict them from consuming cicadas and rodents. Large copperheads did continue to consume the small snakes and lizards that constituted the primary prey of small copperheads.

Although data on the stomach contents of snakes are abundant in the literature, there are few species for which food habits have been studied in any detail other than just as lists of prey taken (Mushinsky 1987). These anecdotal data have been used to review the foraging ecology and morphological adaptations for feeding among species of snakes both in evolutionary terms and as resource partitioning mechanisms (Toft 1985; Mushinsky 1987). However, ontogenetic, seasonal and population differences within a species are important questions that because of the lack of information have rarely been addressed. Only recently has enough relevant data been gathered to begin examining these aspects of the foraging strategies of snakes. Arnold (1993), for example, did a provisional evaluation of the prey size to predator size relationships of snakes and encouraged further study. Because of the dramatic size differences of neonate and adult snakes, ontogenetic shifts in diet are particularly important to this group of organisms. An understanding of the occurrence of the variation in diet of snakes is complicated by the interaction of innate changes in behavior and the role of experience (Halloy & Burghardt 1990). Several recent natural history studies of crotalids have included analysis of diet in relation to snake size and some discussion of this problem (Campbell & Solorzano 1992; Sazima 1992) but data from additional species is still needed.

Prey items from series of the southern copperhead, *Agkistrodon contortrix*, collected at single localities have been documented from

Georgia, North and South Carolina, Mississippi and Eastern Texas (reviewed in Fitch 1960; Gloyd & Conant 1990). A large variety of organisms are consumed by this species which ranges from various invertebrates to reptiles, mammals and birds (Ernst & Barbour 1989). However, because limited information relative to the specimens from which the prey were removed are given, the causes of the variation are difficult to assess. Although geographic variation may be involved, such factors as the season when collected and size of the specimen would also be expected to have influences on the type of prey consumed (Greding 1964). Certain prey will only be abundant during some periods (i.e. frogs after a rain) and restriction of the gape of the jaw will affect the size of prey that small snakes can consume.

The southern copperhead is one of the most abundant snakes in both coniferous woodlands and upland deciduous forests in northeastern Texas (Ford et al. 1991). A collection of *A. contortrix contortrix* in the vertebrate collection at the University of Texas at Tyler were primarily from one area and collected during the same season, but exhibited diversity in body size. These specimens were examined to evaluate size class variation in the diet of this species and also to determine whether differences found reflect ontogenetic changes in prey selection in this species.

MATERIALS AND METHODS

Dietary information was obtained from specimens collected during the summers of 1988-89 at a 515 ha nature camp in Anderson County and from road-killed specimens collected in adjoining Smith County, Texas. This area of northeastern Texas is characterized by predominantly second-growth oak-hickory and short-leaf pine forests with sandy loam soil. Specimens were frozen until size measurements (snout-vent length, SVL) could be taken. The venter of each was then cut longitudinally and the specimen fixed in a 10% solution of formaldehyde. After one week, specimens were washed and transferred to 70% ethyl alcohol. All specimens were placed in the vertebrate collection at the University of Texas at Tyler. Digestive contents were removed from each specimen and identified to as low a taxonomic level as possible. Records of direction of ingestion were also recorded for each item when it was possible to determine. For a general comparison to dietary preferences, the presence of invertebrates and small vertebrates at the resident camp were sampled by pit traps in the same general area and time that the specimens of *A. contortrix* were collected.

Table 1. Prey items recovered from the digestive tracts of southern copperheads, *Agkistrodon contortrix* ($N = 71$ with food). Prey that were unidentifiable at the lowest level were included in numbers for all higher levels as were the snakes with that item.

Prey Type	Range of SVL's of <i>A. contortrix</i> specimens w/prey item	Number of prey items recovered (% of total prey items)	Number of <i>A. contortrix</i> w/prey item (% of total specimens)
Invertebrates			
Cicadidae	28-45 cm	31 (36.9%)	24 (33.8%)
Coleoptera	46 cm	1 (1.2%)	1 (1.4%)
Orthoptera	50 cm	1 (1.2%)	1 (1.4%)
Lepidoptera	29-84 cm	12 (14.3%)	8 (11.3%)
Total Insecta	28-84 cm	48 (57.1%)	36 (50.7%)
Total Arthropoda	28-84 cm	53 (63.1%)	42 (59.2%)
Vertebrates			
<i>Eumeces fasciatus</i>	47 cm	1 (1.2%)	1 (1.4%)
<i>Scincella laterale</i>	86 cm	1 (1.2%)	1 (1.4%)
Scincidae tail only	28-32 cm	4 (4.8%)	4 (5.6%)
Total Scincidae	28-47 cm	10 (11.9%)	10 (14.1%)
<i>Anolis carolinensis</i>	35 cm	1 (1.2%)	1 (1.4%)
Unidentified lizards	24-75 cm	2 (2.4%)	2 (2.8%)
<i>Virginia striatula</i>	28 cm	1 (1.2%)	1 (1.4%)
Unidentified snakes	25-65 cm	2 (2.4%)	2 (2.8%)
Total Squamata	24-75 cm	18 (21.4%)	16 (22.5%)
Mammalia	64 cm	2 (2.4%)	2 (2.8%)
Unidentifiable	34-57 cm	11 (13.1%)	11 (15.5%)
No food	20-81 cm		21
TOTAL		84	96

RESULTS

A total of 84 prey items were found in the gastrointestinal tract of 78% of the 96 copperheads examined (Table 1). Forty-eight specimens were found to contain one prey item, 15 contained two items, seven contained three prey, and one specimen had consumed four prey items. Although 62.5% of the prey were consumed head first, there was no apparent correlation of this factor to the type or size of food item. Specimens of *A. contortrix* were grouped into three size classes representing juveniles and subadults, small adults and large adults and the type of prey relative to the size of the snake is presented in Fig. 1. Cicadas were the most commonly eaten prey (36.9 %) and invertebrates constituted over 63 % of the diet of the specimens examined. Some specimens in all size classes were found to contain insects but small copperheads contained a larger proportion of lizards and snakes (Figure 1). Only the largest copperheads contained mammals and grasshoppers, but this size class also consumed small snakes. The pit traps were found to contain squamata (lizards and small snakes) and arthropoda (primarily aranae, orthoptera, hymenoptera, coleoptera, diptera and isopoda).

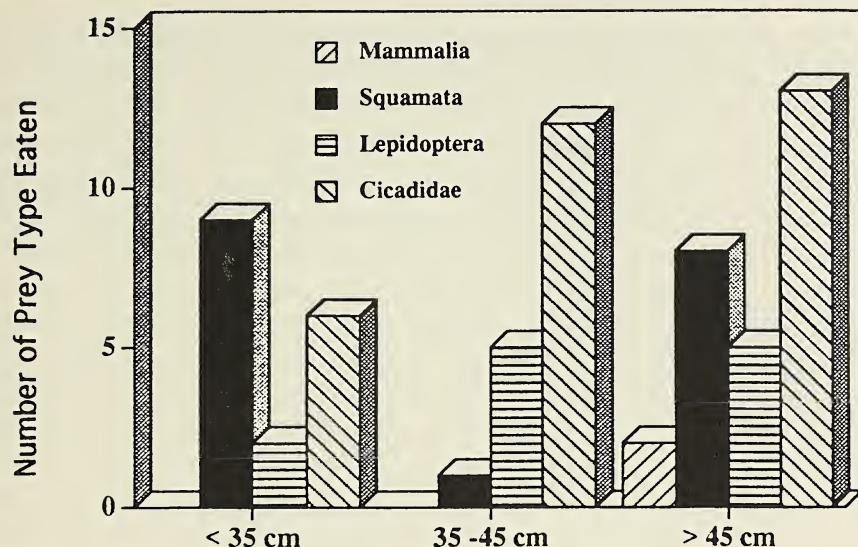


Figure 1. Numbers of prey items removed from the gastrointestinal tract of 71 southern copperheads, *Agkistrodon contortrix*, from northeastern Texas. Snakes are sorted by sizes that correlate generally to neonate and juvenile snakes, subadults, and adults. Some arthropods eaten in small numbers are not included (see text for details).

DISCUSSION

The southern copperhead ranks as a top carnivore in the biotic community of northeastern Texas. Ford et al. (1991) found it to be ubiquitous in all habitats and dominant in all areas except the lowland floodplain where it was second in abundance to the cottonmouth, *Agkistrodon piscivorus*. Its frequency in northeastern Texas would suggest that it has an important role in the ecology of both the pine and hardwood forests of the area.

The present study supports both Curtis' (1949) and Werler's (1978) observations that in eastern Texas the most common prey items taken by this species are cicadas (37%, Table 1). It is important in analysis of prey selection by predators to have knowledge of the prey abundance for the species being studied. In this study, pit traps did not sample all possible copperhead prey equally (especially arboreal insects such as the cicada) and turned out not to be a completely adequate technique for evaluating prey abundance for copperheads. Because of this it is impossible to determine if these copperheads were preferentially foraging for cicadas or are just active in places where the cicadas occur. Since these insects are generally located in trees at least after emergence from the ground, either hypotheses would require the snakes to climb. Copperheads are known to climb bushes, vines and even high up in trees

(Fitch 1960; Werler 1978; Gloyd & Conant 1990). It is suggested here that this arboreal activity most likely reflects this species searching for this prey because the other food items of copperheads are terrestrial.

Cicadas are very abundant in eastern Texas during mid to late summer when most of the specimens examined during this study were collected. The abundance of this prey item in these specimens is not surprising but points to a problem that can occur in dietary studies of snakes. Specimens often come primarily from one collecting trip or time period and if seasonal variation occurs in prey abundance, analysis of those snakes may give a mistaken view of the species diet. Copperheads collected in the spring or fall in east Texas would likely present a very different picture of the prey taken by this population because cicadas would not be available. A difference in when collections were made or the particular habitats collected might explain why frogs (*Rana*) predominated in Clark's (1949) study of this species in north central Louisiana. Indeed, Greding (1964) suggested that the ground skink, *Scincella laterale* was the most important prey for this species during the spring in eastern Texas. Studies from one locality in which seasons of the collection are noted are obviously important.

Because the copperheads in this study were collected during the same season from similar habitats in a small area, differences in prey taken by different size classes most likely represent ontogenetic variation in diet. Smaller copperheads contained a larger proportion of lizards and snakes (Figure 1). This may reflect difficulty that smaller snakes would have attempting to eat cicadas. Only the largest snakes consumed mammals, even though in captivity rodents are readily eaten by medium-sized copperheads. *Peromyscus*, *Reithrodontomys* and *Blarina* are relatively common in the same habitats as copperheads. In other localities, small mammals apparently are quite important prey items. For example, in southern copperheads from North and South Carolina mammals ranked second (37.1%) in the number of prey items consumed (Brown 1979). Lepidopteran larvae and cicadas were commonly found in the larger copperheads examined in this study. Why more rodents were not taken by these east Texas copperheads is unknown. One observation that can be made is that the larger snakes appear to have a wider dietary niche than do the young copperheads. As copperheads grow it might be expected that larger prey items (i.e. cicadas and mammals) would be added to their diet but small snakes and lizards were also taken by the largest copperheads. In most species that have been studied, larger snakes tend to not eat the same small prey taken as juveniles; but the

change from juvenile prey items is not universal in snakes nor even well documented in many species (Shine 1991; Arnold 1993). For example, Concho water snakes, *Nerodia harteri*, continue to take small fish as adult snakes (Greene et al. 1994). When ontogenetic shifts in diet in snakes do occur, these changes can be related to increased motor skills and alterations of habitat use in addition to simple structural enlargement of the animal (Lind & Welsh 1994).

Gloyd & Conant (1990) reviewed the diet of *Agkistrodon contortrix* from a number of localities and suggested that geographical variation in prey taken occurs. Although this conclusion is likely correct, the various collections involved may have bias samples, i.e. larger specimens, only those dead on roadways, or animals collected only from certain habitats. Differences observed among populations may also reflect seasonal variation in prey availability or ontogenetic changes in the foraging activities of young and adult copperheads. This study suggests that the latter can be an important factor that should be considered.

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COMPARISON OF CEDAR GLADES AND ASSOCIATED WOODLANDS OF THE SOUTHERN EDWARDS PLATEAU

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Abstract.—Phytosociological, physical and chemical characteristics were examined in seven cedar glade communities and their associated woodlands in the southern part of the Edwards Plateau of central Texas. Of 15 woody and five succulent species found in the two communities, two species were restricted to the cedar glades and eight to the woodlands. Total mean density for woody and succulent plants in the cedar glades was 1,146 plants/ha and for the woodlands was 10,719 plants/ha. Total mean basal area for woody and succulent plants in the cedar glades was 2.59 m²/ha and 57.58 m²/ha for the woodlands. Mean grass cover for the cedar glades was 11% and 3% for the woodlands. Mean herbaceous cover for the cedar glades was 2%, but for the woodlands it was less than 1%. Cedar glades were found to be significantly higher in mean light levels, pH, sulfur and sodium while woodlands were significantly higher in mean slope angle, soil depth, salinity, percent organic content and magnesium. Shallow soil combined with low water availability during the summer appears to prevent the establishment of woody species in the cedar glades while low light levels in the woodlands probably limits grasses and herbaceous growth to the open cedar glade habitat.

Cedar glades have been recognized as separate communities for many years (Harper 1926; Freeman 1933; Steyermark 1940; Erickson et al. 1942; Quarterman 1950a; Baskin & Baskin 1975; Nelson & Ladd 1980). They are defined as open grassy or herbaceous areas with shallow soils, little woody vegetation and surrounded by a *Juniperus* woodland or forest (Harper 1926; Freeman 1933; Quarterman 1950b; Baskin & Baskin 1978). There may be a few scattered small trees or islands of woody vegetation present within the cedar glades (Kucera & Martin 1957).

Cedar glades and glade like communities have been studied extensively in the southeastern and southcentral United States. Several studies in Missouri (Erickson et al. 1942; Kucera & Martin 1957) and Tennessee (Quarterman 1950a) indicated that soil and bedrock formations affected the character of cedar glades. In addition, Freeman (1933) suggested that soil depth, fertility and water content were the main influences on the ecology and flora of Tennessee cedar glades. Baskin & Baskin (1985a) found that temperature was influential in the germination stage of annual plant life cycles in cedar glades of the southeastern United States. The most common species occurring in the

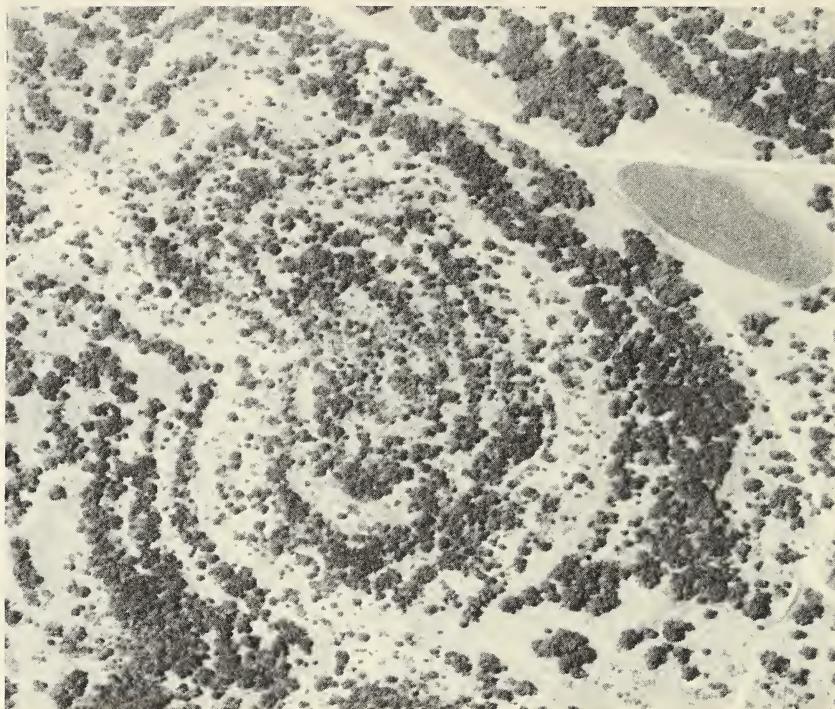


Figure 1. Aerial photograph of a hilltop in the southern part of the Edwards Plateau region in northern Bexar County, Texas. Dark bands are *Juniperus* woodlands and lighter bands are the open cedar glades.

cedar glades of Kentucky (Baskin & Baskin 1975; 1978; 1985a) and Tennessee (Harper 1926) were in the Compositae, Leguminosae and Gramineae. Baskin & Baskin (1978; 1986) suggested that cedar glades have been sources of speciation due to the high number of endemics found in these communities. Furthermore, many cedar glade endemics require high light levels and are shade intolerant (Baskin & Baskin 1988).

Although there are over ten million hectares of *Juniperus* woodlands in the Edwards Plateau of central Texas (Gould 1969), only the study by Redfern (1980) addressed Edwards Plateau cedar glade vegetation. He compared the floristic composition of the bryophyte communities in Tennessee, southwest Missouri and the Edwards Plateau of Texas and suggested that differences found in the Texas cedar glades maybe due to their lower soil moisture levels.

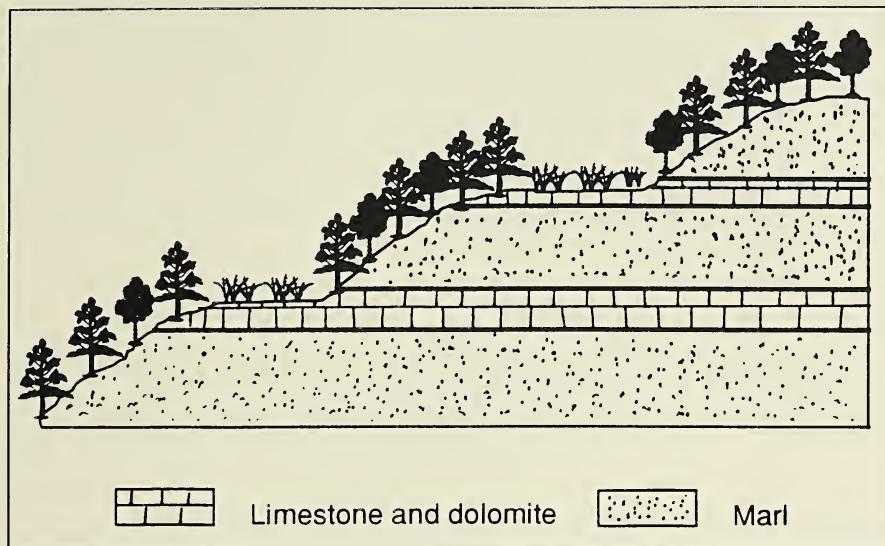


Figure 2. Cross sectional schematic drawing of cedar glades and associated woodlands in the southern part of the Edwards Plateau, Bexar County, Texas. Soils are deeper and have a higher organic content below the woodlands than the cedar glades. Stair-step appearance is caused by different weathering and erosion of the limestone and marl bedrocks.

There appear to be two types of central Texas cedar glades. Hillside cedar glades are more or less concentric narrow bands of herbaceous vegetation that alternate with bands of *Juniperus* woodlands. When viewed from the air, these bands form a "bulls-eye" around the hill (Fig. 1) and seem to correspond to a "stair-step" topography (Riskind & Diamond 1988; Woodruff 1993), commonly seen in the Edwards Plateau (Fig. 2). Cedar glades generally occur on the outer edge of the steps while the woodlands occur on the inner edge. This topography is due to different weathering and erosion rates of alternating bands of soft marl and hard limestone and dolomite which compose the Glen Rose Formation, the bedrock material of the area (Woodruff 1993). Kucera & Martin (1957), Hendrickson & Davis (1980) and Gates et al. (1982) also reported the presence of a similar "stair-step" topography and vegetational banding associated with cedar glades in Missouri. The second type of glade found in the Edwards Plateau region maybe described as a microglade. They are usually smaller than the hillside glades and are generally found on more level topography. They are normally circular in appearance and have a solid rock center.

The presence of the cedar glades on the Edwards Plateau has been noted in the past (Steyermark 1934) and although the geology and soils have been described (Marsh & Marsh 1993a; 1993b; Wilding 1993; Woodruff 1993), comparative vegetational studies appear to be lacking. The objective of this study was to describe and compare the phytosociological, physical and chemical characteristics of narrow hillside cedar glades and the surrounding woodlands of the Edwards Plateau in southcentral Texas.

MATERIALS AND METHODS

The study area is located in Bexar County, northwest of San Antonio, Texas on the southern edge of the Edwards Plateau ($98^{\circ}37'W$ and $29^{\circ}37'N$). Area climate is classified as subtropical-subhumid with a mean annual temperature of $20^{\circ}C$ (Arbingast et al. 1976). The highest mean monthly temperatures occur in July and August ($28.9^{\circ}C$) and the lowest in January ($10.9^{\circ}C$). Average annual precipitation is 71.1 cm with peaks in May and September (Gale Research 1992). Cedar glades and their associated woodlands selected for this study were considered representative of those communities in the area. None of the selected cedar glades or their associated woodlands had indications of fire, cutting, or other major disturbances. Site selection was based on cedar glade size (>40 m long and >5 m wide), slope ($<15^{\circ}$) and the lack of open, glade-like areas in the *Juniperus* woodland uphill from the cedar glade. Sample adequacy was not addressed because the cedar glades and associated woodlands were small enough that the entire community was sampled in many cases.

The quadrat technique (Clements 1905; Van Auken & Bush 1995) was used to collect data from October 1993 through January 1994. Quadrats (5 by 5 m) were placed contiguously along a single transect line in the center of each cedar glade and each associated woodland, perpendicular to the slope. All woody and succulent plants ≥ 50 cm in height and ≥ 3 cm basal circumference were identified to species (following Correll & Johnson 1970) and their basal circumference was measured and recorded. *Opuntia phaeacantha*, *Echinocereus caespitosus*, *Yucca rupicola*, *Dasyliion texanum* and *Mammillaria vivipara* were considered succulents.

Densities of *O. phaeacantha*, *Y. rupicola* and *D. texanum* were determined but basal areas were not measured because of the growth

habit of these species. Basal areas of *Acacia roemeriana* and *Berberis trifoliolata*, multistemmed species, were determined by measuring the outer circumference of the stem clump rather than individual stems. The number of quadrats measured in each cedar glade and associated woodland ranged from 8 to 12, depending on the length of the community.

Five quadrats (1 m^2) were used to count and identify seedlings $<50\text{ cm}$ tall. Five quadrats (0.1 m^2) were used to visually estimate percent grass cover and percent herbaceous plant cover. At the time of the study, grasses were past flowering and herbaceous plants were desiccated, thus preventing identification of individuals to species. Percent grass cover (grasses and sedges) included both live and dead plant material. The 1 m^2 and 0.1 m^2 quadrats were located in the corners and center of each 25 m^2 quadrat.

Slopes of the cedar glades and associated woodlands were measured using a Brunton® compass. Aspect was measured in each cedar glade and associated woodland with a Sylva® compass. Light levels were measured with a LI-COR® LI-188 integrating quantum sensor in one cedar glade and associated woodland between 1:00 p.m. and 2:00 p.m. on a cloudless day (19 May 1994). Eighteen measurements were recorded in the cedar glade and seventeen in the associated woodland. Soil depths were measured along each transect using a five mm diameter iron bar driven into the soil every 0.5 m. Soil samples were collected in each cedar glade and each associated woodland at the beginning, middle and end of each transect. The samples were air dried and sieved through a number 10 mesh sieve. A total of 42 samples, three from each cedar glade and three from each associated woodland were sent to Texas A&M University Soil Testing Laboratory for measurement of calcium, magnesium, potassium, sulfur, sodium, phosphorous, nitrogen, salinity and pH. Soil organic carbon was determined using the loss-on-ignition method (Broadbent 1965). Samples were oven dried at 90°C , cooled, weighted, heated to 600°C for three hours and reweighed. The loss of weight was considered the amount of organic carbon in the sample.

Phytosociological, physical and chemical differences between cedar glades and associated woodlands were tested using a paired Student's *t* test (Ott 1993). All analyses were conducted with the SAS computer application system (SAS Institute 1982).

Table 1. Percent frequency of species in seven cedar glades and seven woodlands in northern Bexar County, Texas. A bar (—) indicates species was not found in that community type.

Taxon	Cedar Glades	Woodlands
<i>Opuntia phaeacantha</i>	100%	57%
<i>Juniperus ashei</i>	86%	100%
<i>Diospyros texana</i>	71%	100%
<i>Acacia roemeriana</i>	57%	100%
<i>Rhus virens</i>	57%	71%
<i>Echinocerous caespitosus</i>	43%	—
<i>Quercus fusiformis</i>	43%	100%
<i>Sophora secundiflora</i>	43%	100%
<i>Yucca ripicola</i>	43%	43%
<i>Dasyllirion texanum</i>	29%	14%
<i>Eysenhardtia texana</i>	29%	14%
<i>Mammillaria vivipara</i>	14%	—
<i>Berberis trifoliolata</i>	—	100%
<i>Bumelia lanuginosa</i>	—	57%
<i>Foresteria reticulata</i>	—	29%
<i>Celtis laevigata</i>	—	29%
<i>Quercus stellata</i>	—	29%
<i>Ulmus crassifolia</i>	—	14%
<i>Cercis canadensis</i>	—	14%
<i>Ungnadia speciosa</i>	—	14%

RESULTS

Visually, cedar glades and the surrounding woodlands are physically and biologically different allowing for easy distinction between the two communities (Figs. 1 & 2). A total of 20 species were present in the two communities, 15 woody species and five succulents. Two species were confined to the cedar glades, eight species were confined to the woodlands and 10 were found in both communities (Table 1). Only *Opuntia phaeacantha* was found in all seven cedar glades, but *Juniperus ashei*, *Diospyros texana*, *Acacia roemeriana*, *Quercus fusiformis*, *Sophora secundiflora* and *Berberis trifoliolata* were found in all seven woodlands (Table 1). Mean total woody plant and succulent density of the cedar glades was $1,146 \pm 60$ plants/ha ($\bar{x} \pm SE$) and was significantly different ($t = 5.45$, $P = 0.002$) from the mean total woody plant and succulent density of the woodlands with $10,716 \pm 1,752$ plants/ha (Table 2). High density species in the cedar glades were *O. phaeacantha*, *J. ashei*, *Q. fusiformis*, *Echinocereus caespitosus* and *A. roemeriana*. High density species in the woodlands were *J. ashei*, *D. texana*, *S. secundiflora*, *Q. fusiformis* and *Rhus virens*.

Mean total woody plant and succulent basal area of the cedar glades was 2.59 ± 0.91 m²/ha and was significantly different ($t = 6.62$, $P = 0.001$) from the woodlands at 57.58 ± 8.73 m²/ha. High basal area

Table 2. Mean density (plants/ha) and mean basal area (m^2/ha) for woody and succulent species, >50 cm tall, found in cedar glades (GL) and woodlands (WD) in northern Bexar County, Texas. A bar (—) indicates species was not present in that community. A (**) indicates species presence in those communities but basal area was not included in the table because of the species growth habit.

Taxon	Mean Density		Mean Basal Area	
	GL	WD	GL	WD
<i>Opuntia phaeacantha</i>	300	54	**	**
<i>Juniperus ashei</i>	157	2,363	0.76	22.56
<i>Quercus fusiformis</i>	137	1,167	0.03	11.18
<i>Echinocerous caespitosus</i>	102	—	0.46	—
<i>Acacia roemeriana</i>	95	381	0.41	0.10
<i>Sophora secundiflora</i>	81	1,904	0.12	3.70
<i>Rhus virens</i>	73	1,007	0.54	4.25
<i>Yucca rupicola</i>	71	57	**	**
<i>Dasyliion texanum</i>	70	46	**	**
<i>Diospyros texana</i>	50	1,971	0.12	4.36
<i>Berberis trifoliolata</i>	—	930	—	11.01
<i>Quercus stellata</i>	—	694	—	0.34
<i>Bumelia lanuginosa</i>	—	63	—	0.06
Other *	10	79	0.15	0.02
Total	1,146	10,716	2.59	57.58

* Species with densities less than 50 plants/ha and basal areas less than 0.10 m^2/ha , including *Eysenhardtia texana* and *Mammillaria vivipara* found in the cedar glades and *Cercis canadensis*, *Ungnadia speciosa*, *Celtis laevigata*, *Forestiera reticulata*, *Eysenhardtia texana* and *Ulmus crassifolia* found in the woodlands.

species in the cedar glades were *J. ashei*, *R. virens*, *E. caespitosus* and *A. roemeriana*. High basal area species in the woodlands were *J. ashei*, *Q. fusiformis*, *B. trifoliolata*, *D. texana*, *R. virens* and *S. secundiflora* (Table 2).

Of the eighteen species of seedlings found in the study, one unidentified species was restricted to the cedar glades (Table 3). *Quercus stellata*, *Celtis laevigata*, *Salvia ballotaeiflora*, *Ulmus crassifolia*, *Yucca rupicola* and *Forestiera reticulata* were restricted to the woodlands. Eleven species were common to both communities (Table 3) and four species (two unidentified) were detected as seedlings but not adults. Seedling density in the cedar glades was 33 plants/100 m^2 and in the woodlands it was 941 plants/100 m^2 ($t = 2.21$, $P = 0.01$).

Mean cedar glade grass cover ($11 \pm 5\%$) was over three times higher than the mean woodland grass cover ($3 \pm 0.4\%$), although the two communities were not significantly different ($t = 1.5$, $P = 0.18$). The mean herbaceous plant cover was significantly greater in the cedar glades ($2 \pm 0.4\%$) than the woodlands ($0.4 \pm 0.2\%$) ($t = 2.65$, $P =$

Table 3. Mean density (plants/100 m²) of woody and succulent seedlings (<50 cm tall), for cedar glade and woodland communities in Northern Bexar County, Texas. A (+) indicates a density less than one plant/100 m² and a bar (—) indicates that species was not present in that community.

TAXON	CEDAR GLADES	WOODLANDS
<i>Juniperus ashei</i>	15	311
<i>Quercus fusiformis</i>	7	369
<i>Opuntia phaeacantha</i>	3	3
<i>Acacia roemeriana</i>	2	17
<i>Berberis trifoliolata</i>	1	70
<i>Bumelia lanuginosa</i>	1	3
<i>Diospyros texana</i>	1	3
<i>Rhus virens</i>	1	15
<i>Sophora secundiflora</i>	1	107
<i>Eysenhardtia texana</i>	+	3
<i>Quercus stellata</i>	—	15
<i>Celtis laevigata</i>	—	12
<i>Salvia ballotaeiflora</i>	—	1
<i>Ulmus crassifolia</i>	—	1
<i>Yucca ripicola</i>	—	1
Other*	—1	—10
Total	31	941

* *Foresteria reticulata*, isolated in the woodlands and two unidentified species, one isolated in the cedar glades and one found in both communities.

0.04). Mean light levels were ten times greater in the cedar glades ($1990 \pm 9 \mu\text{mol}/\text{m}^2/\text{s}$) than in the woodlands ($189 \pm 46 \mu\text{mol}/\text{m}^2/\text{s}$) ($t = 38.57$, $P = 0.0001$).

There was no significant difference ($t = 2.20$, $P = 0.07$) between the mean slope angle of the cedar glades ($7.7 \pm 1.7^\circ$) and the woodlands ($13.0 \pm 1.8^\circ$). Aspect ranged from 113° - 298° with four locations southwest, two southeast and one northwest. Mean soil depth in the woodlands was 8.1 ± 1.2 cm and was 2.4 times greater than the mean soil depth in the cedar glades ($t = 3.8$, $P = 0.01$; Table 4). Mean percent organic carbon, salinity and magnesium concentrations were all significantly higher ($P < 0.01$) in the woodlands compared with the cedar glades. Mean pH, sulphur and sodium content were all significantly higher ($P < 0.01$) in the cedar glades (Table 4). Mean calcium, potassium, phosphorus and nitrogen content were not significantly different (all paired t-tests had $P > 0.05$) between the two communities (Table 4).

DISCUSSION

Although never vegetatively described, cedar glades are common biotic features in the Edwards Plateau. They have a low woody species

Table 4. Comparison of cedar glade and woodland soils in the southern part of the Edwards Plateau. Values are $\bar{x} \pm 1$ SE. An * indicates a significant difference (Student's paired t-test $P \leq 0.01$).

Parameter	Cedar Glades	Woodlands
Salinity (mmol/cm ³)	0.52 ± 0.03	0.75 ± 0.06*
Organic Content (%)	14 ± 1	26 ± 2*
pH	8.0 ± 0.0	7.6 ± 0.1*
Soil Depth (cm)	3.4 ± 0.7	8.1 ± 1.2*
Calcium (mg/kg)	26,561 ± 60	24,105 ± 1,677
Sulphur (mg/kg)	617 ± 107	326 ± 58*
Magnesium (mg/kg)	279 ± 37	379 ± 37*
Potassium (mg/kg)	230 ± 16	349 ± 65
Sodium (mg/kg)	30 ± 3	22 ± 2*
Phosphorus (mg/kg)	13 ± 2	17 ± 2
Nitrogen (mg/kg)	8 ± 2	15 ± 2

density with individuals of small stature but a relatively high grass cover and other herbaceous plant cover. While herbaceous species were not identified in this study, preliminary results from a study of the microglades suggest many are annual species.

Southeastern and southcentral cedar glades have many characteristics similar to the Edwards Plateau cedar glades, including a limestone bedrock. The most distinctive characteristics of cedar glades in these three areas of the United States are the low density of woody plants, shallow soil and the surrounding *Juniperus* woodland. *Juniperus ashei* was one of the most common woody species encountered in this study, while in the woodlands of the southeastern and southcentral United States, *Juniperus virginiana* was the most common woody species encountered (Harper 1926; Quartermann 1950b; Kucera & Martin 1957). The percent grass cover we observed in the cedar glades was similar to that reported in the cedar glades of the southcentral United States. Quartermann (1950b) indicated high grass and herbaceous cover in the open glades of Tennessee, but minor herbaceous cover in the associated woodlands. In Missouri cedar glades, Kucera & Martin (1957) reported higher grass cover than herbaceous cover. This study revealed a higher grass cover in the cedar glades when compared to the associated woodlands, although the herbaceous cover in this study was lower than expected. The low herbaceous plant cover reported in this study may be due to sampling in the fall and early winter months, when many winter annuals would be rosettes and summer annuals would have completed their life cycles (Baskin & Baskin 1985a).

In addition to the presence of annuals in the Edwards Plateau cedar glades, *Nostoc commune* and various bryophytes were common but not

quantified. *Nostoc commune* and the bryophytes were especially common in areas with exposed rock or soil less than one cm deep. Quarterman (1950b) found that *N. commune* formed the basis for vegetation mats in shallow depressions in Tennessee cedar glades. *Opuntia* spp. were common in many Tennessee and Kentucky cedar glades (Freeman 1933; Quarterman 1950b; Baskin & Baskin 1978); *O. phaeacantha* was the only *Opuntia* species found in all of the cedar glades examined in this study.

The Edwards Plateau *Juniperus* woodlands have higher woody species densities, higher basal areas, lower grass and herbaceous cover and deeper soils than the associated cedar glades. Species of *Juniperus*, *Quercus*, *Rhus*, *Bumelia*, *Cercis* and *Ulmus* were found in the woodlands in this study as well as those in Tennessee (Quarterman 1950b) and Missouri (Kucera & Martin 1957). In measuring successional stages of cedar glades in Tennessee, Quarterman (1950b) found *Rhus aromatica* and *Foresteria ligustrina* in the ecotone between the cedar glade and woodland. Field observations in the present study indicated that most of the *Rhus virens* and *Foresteria reticulata* plants were located at the woodland edge.

Soil characteristics were also similar between the cedar glades of the southcentral United States and the Edwards Plateau. The higher pH values in the cedar glades compared to the woodlands in this study were similar to the trend found by Kucera & Martin (1957) in Missouri, although their pH values were lower in both communities. The shallowness of the soils in the cedar glades was visually evident in this study and has been reported in previous studies of cedar glades of the southcentral United States (Harper 1926; Freeman 1933, Kucera & Martin 1957; Quarterman 1950b). Quarterman (1950b) and Kucera & Martin (1957) demonstrated that soil moisture in southeastern United States cedar glades was lower than in the soils of the surrounding woodlands. While not measured in this study, Wilding (1993) reported lower soil moisture, lower fertility and higher runoff in the cedar glades of the Edwards Plateau compared to the associated woodlands. Quarterman (1950b) found 28.3% soil organic content in the woodlands surrounding the cedar glades of Tennessee, which was similar to the 26 \pm 5% reported here (Table 3).

The higher organic content and deeper soils of the woodlands are probably due to capture of run-off from the hillside cedar glade above (Wilding 1993). See Fig. 2. Initially, this would deepen the soils of the

woodland and allow for establishment and growth of woody vegetation and secondarily, litter deposition from the woodland itself would continue the process.

The low soil moisture and high runoff rates reported by Wilding (1993) in combination with the high light levels at the soil surface recorded in this study, would cause high temperatures and increase evaporation from the shallow cedar glade soils (Freeman 1933). These factors probably promote higher grass and annual plant cover as well as low density of woody seedlings in the cedar glades compared to the associated woodlands.

The cedar glades of the southeastern and southcentral United States appear to be larger and wider than the Edwards Plateau cedar glades and often contain soil filled cracks that support adult trees (Quarterman 1950a; Baskin & Baskin 1985b). The Edwards Plateau cedar glades contained a few small cracks that supported only shrub sized individuals but no adult trees. These cracks maybe due to differences in limestone formations (Quarterman 1950b). Nelson & Ladd (1980) suggested that differences in the size of cedar glades maybe the result of different rates of erosion and runoff of bedrock materials, where dolomite based cedar glades could be as large as 2,000 ha but limestone based cedar glades were narrower and smaller.

The density of woody plants found in the woodlands was much higher than other reported values for the Edwards Plateau (Van Auken et al. 1981; Van Auken 1988). This discrepancy is probably due to differences in methods of data collection (quadrat versus the point-centered-quarter method) and because this study measured only the woodland and not interspersed openings. Basal area measurements were similar to previously reported values (Van Auken 1988).

The shallow soil depth, high light levels and seasonally low soil moisture are probably the most influential factors in determining woody plant density, basal area and community species composition in the Edwards Plateau cedar glades. High light levels and low soil moisture probably prevented woody seedlings from becoming established as well as preventing growth to any appreciable size. Conversely, in the woodlands, the deeper soils, higher soil moisture content, higher organic content and lower light levels due to shading, probably provide a better habitat for establishment and growth of many woody species, but to the detriment of the grasses and other herbaceous plants.

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**RODENT-HABITAT ASSOCIATIONS
IN A CHIHUAHUA DESERT GRASSLAND COMMUNITY
IN TRANS-PECOS TEXAS**

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Abstract.—Four 100 by 100 m grids were removal-trapped in a desert grassland community in Hudspeth County, Texas during seven trapping sessions from October 1992 through August 1993. Two grids were placed on a sandy loam range site and two grids on a loamy range site. The more densely vegetated sandy loam site supported scattered longleaf yucca (*Yucca elata*), Mormon tea (*Ephedra trifurca*), black grama (*Bouteloua eriopoda*), sand dropseed (*Sporobolus cryptandrus*) and blue grama (*Bouteloua gracilis*). The loamy site was characterized by winterfat (*Ceratoides lanata*), Torrey yucca (*Yucca torreyi*), longleaf yucca, mesquite (*Prosopis glandulosa*), burrograss (*Scleropogon brevifolius*) and blue grama. Nine rodent species (227 specimens) were trapped during 6,400 trap-nights. A total of 142 specimens (62.6%) were trapped on the sandy loam site and 85 specimens (37.4%) on the loamy site. The three most commonly trapped species were *Onychomys arenicola* (29.5%), *Peromyscus leucopus* (18.9%) and *Perognathus flavus* (14.5%). *Neotoma micropus* and *Peromyscus maniculatus* accounted for 19.8% of all specimens. Body weights of *P. flavus*, *P. leucopus* and *O. arenicola* were greater for individuals on the sandy loam site.

Accounts of rodent-habitat associations in the Texas Trans Pecos (e.g. Schmidly 1977) suggest that for many species habitat "preferences" are complex and highly variable throughout the region. However, there are relatively few descriptions of these associations for this geographical area. Preliminary trapping in Hudspeth County (Rylander et al. 1991; Wester et al. 1994) demonstrated patchiness in rodent distributions near Fort Hancock and Sierra Blanca, especially in the latter location. Because Chihuahuan Desert grasslands often support inclusions of shrub-dominated vegetation related to soil differences, it is reasonable to expect corresponding differences in rodent populations between shrub and grass-dominated communities. The present study was undertaken to compare rodent populations between a grass-dominated loamy range site and a grass-shrub mosaic in a sandy loam site in a Chihuahuan Desert grassland.

METHODS

The study was conducted in a Chihuahuan Desert grassland reserve area of the Texas Low-Level Radioactive Waste Disposal Site, about 10 km SE of Sierra Blanca, Hudspeth County, Texas (elev. 1832 m). Mean

Table 1. Site characteristics of the sandy loam site and loamy site (Wester et al. 1994).

	Sandy Loam Site	Loamy Site
Soil Texture		
Sand	70%	58%
Clay	14%	24%
Silt	16%	18%
Species composition		
<i>Bouteloua eriopoda</i>	47.1%	8.3%
<i>Sporobolus cryptandrus</i>	18.5%	2.2%
<i>Bouteloua gracilis</i>	10.1%	41.3%
<i>Scleropogon brevifolius</i>	8.8%	30.3%
<i>Muhlenbergia arenicola</i>	3.3%	4.8%
<i>Ephedra trifurca</i>	0.1%	0.0%
<i>Yucca elata</i>	0.1%	0.1%
<i>Prosopis glandulosa</i>	0.1%	0.1%
Foliar cover	63%	35%

annual temperature is 16.7° C and mean annual precipitation is 308 mm, 67% of which occurs from July through October (NOAA, 1993).

There is no published soil survey of Hudspeth County. As part of a comprehensive vegetation/soils description of the reserve area (Wester et al. 1994), two range sites were identified: a sandy loam range site and a variant of a loamy range site (Table 1). Site names follow range site descriptions for Trans-Pecos Texas published by the National Resource Conservation Service, formerly the Soil Conservation Service. A fine sandy loam soil characterizes the sandy loam site; underlying this is a sandy clay loam, described to a depth of 142 cm. The sandy loam site is characterized by widely scattered longleaf yucca (*Yucca elata*) and Mormon tea (*Ephedra trifurca*); black grama (*Bouteloua eriopoda*) dominates the herbaceous understory, with lesser amounts of sand dropseed (*Sporobolus cryptandrus*) and blue grama (*Bouteloua gracilis*). In contrast, the loamy site has fine sandy loam in the surface 31 cm, underlain by a sandy clay loam to 163 cm; additionally, discontinuous plates of caliche are present between 36 and 109 cm. Winterfat (*Ceratoides lanata*), Torrey yucca (*Yucca torreyi*), longleaf yucca and mesquite (*Prosopis glandulosa*) are the most common shrubs; burrograss (*Scleropogon brevifolius*) and blue grama dominate the understory. Foliar cover (recorded as 0-25%, 25-50%, 50-75% or 75-100%) was estimated by measuring ground cover in the 100 m² area to the NW of each trapping station. These measurements were made in August, 1993, when vegetation cover was greatest. A more detailed description of vegetation and soils for these sites may be found in Wester et al. (1994).

Table 2. Number of rodents trapped (N), sex ratio (m/f) and mean body weights (MW) for rodents on a sandy loam site and a loamy site, October, 1992- August, 1993.

	Sandy Loam Site			Loamy Site		
	N ¹	m/f ¹	MW ³	N ¹	m/f	MW
<i>Perognathus flavus</i>	20	1:0	7.6 ^A	13	1:2	6.9 ^B
<i>Dipodomys merriami</i>	2 ^a			18 ^b		
<i>Dipodomys ordii</i>	3			1		
<i>Reithrodontomys megalotis</i>	6 ^a			0 ^b		
<i>Reithrodontomys montanus</i>	8 ^a			1 ^b		
<i>Peromyscus leucopus</i>	38 ^a	1:2	19.9 ^A	5 ^b	4:0	17.5 ^B
<i>Peromyscus maniculatus</i>	15			8		
<i>Onychomys arenicola</i>	31		18.2 ^A	36		
<i>Neotoma micropus</i>	19 ^a			3 ^b	1:4	17.4 ^B

¹ Frequency of capture=N/no. of trap nights. Site values for a species followed by a different lower case letter are significantly different ($P < 0.05$).

² Sex ratios with an asterisk are significantly different from 1:1 ($P < 0.05$).

³ Body weights (g) for a species followed by a different upper case letter are significantly different ($P < 0.05$).

Four 100 by 100 m grids were established in each range site. Sherman live-rodent traps were placed at 10 m intervals on each grid (100 traps/grid), baited with rolled oats before dark and checked the following morning. Rodents were trapped during seven sessions: 24-25 October 1992; 31 October - 1 November 1992; 5-6 December 1992; 21-23 December 1992; 13-15 January 1993; 17 May 1993 and 10-12 August 1993. Trapped individuals were weighed, measured, sexed and deposited as study skins with the holdings of the Museum at Midwestern State University, Wichita Falls, Texas.

Mean body weights for *Perognathus flavus*, *Peromyscus leucopus* and *Onychomys arenicola* were compared between the two sites using Student's t-test. Trapping success (frequency of traps with animals) between the two sites was compared with a 2x2 contingency table and a likelihood ratio (G) statistic (Sokal & Rohlf 1982:731). Observed sex ratios were compared to an hypothesized 1:1 ratio with a likelihood ratio (G) test (Sokal & Rohlf 1982:704). Nomenclature and species sequence follow that of Jones et al. (1988).

RESULTS AND DISCUSSION

Nine rodent species (227 specimens) were trapped during 6,400 trap-nights (Table 2), with an overall trap success of 3.65 animals per 100 trap-nights. During this study, 142 specimens (62.6%) were trapped on

the sandy loam site and 85 specimens (37.4%) on the loamy site (Table 2). Eight spotted ground squirrels (*Spermophilus spilosoma*) were also collected but not included in the analysis. The three most commonly trapped species were *Onychomys arenicola* (=*O. torridus*) (29.5%), *Peromyscus leucopus* (18.9%) and *Perognathus flavus* (14.5%), which together accounted for 63.0% of all specimens caught. *Neotoma micropus* and *Peromyscus maniculatus* accounted for 19.8% of all specimens.

Perognathus flavus was trapped as frequently ($P>0.221$) on the sandy loam site as on the loamy range site (Table 2). Given that percent foliar cover on the sandy loam site was 63% and composed of midgrasses, whereas foliar cover of the loamy site was only 35% and composed largely of short grasses (Table 1), this result does not support Schmidly's (1977) observation that *P. flavus* favors habitats with relatively short grass cover. Lemen & Rosenzweig (1978) reported that in New Mexico, *P. flavus* preferred grass and near grass habitats over open habitat, and in Brewster County, Texas, Porter (1962) indicated that the presence of rocks was important for this species. Rock cover was virtually nonexistent on the two sites examined during this study.

Dipodomys merriami was by far the more common member of the genus in the area and was trapped more frequently ($P<0.0001$) on the loamy site than on the sandy loam site (Table 2). This common rodent is found in a variety of habitats in Trans-Pecos Texas (Schmidly 1977). Results of this study did not find the uniformity of distribution for this species that was observed by Rylander et al. (1991), who sampled a more xeric habitat at a lower elevation in Hudspeth County. Since only three specimens of *D. ordii* were trapped on the sandy loam site and one on the loamy site, results of this study could not distinguish different habitat preferences in this species. On the other hand, Lemen & Rosenzweig (1978) showed that in New Mexico *D. ordii* preferred open habitat over grass habitat.

Both species of *Reithrodontomys* (*R. megalotis* and *R. montanus*) appeared to exhibit a preference for the more heavily vegetated sandy loam site, with 14 of the 15 specimens in this genus trapped on this site. Expected values less than 5 suggest cautious interpretation of the statistical significance of the analyses. This result is consistent with the commonly recognized habitat for the species of "sandy soil with dense ground cover" (Schmidly 1977:100). Also, the nine specimens of *R. montanus* collected during this study are of additional interest, since by

1977 only six specimens had been reported for Trans-Pecos Texas (and none in Hudspeth County) by Schmidly (1977).

Peromyscus leucopus, the second most-frequently trapped rodent in this study (43 specimens), was almost twice as common as *P. maniculatus* (23 specimens). *Peromyscus leucopus* was trapped more frequently ($P < 0.0001$) on the heavily vegetated sandy loam site (Table 2). Published preferred habitats for *P. leucopus* include loam soils and brushy, weedy parts of grasslands (Schmidly 1977), essentially like the sandy loam site. *Peromyscus maniculatus* was trapped equally frequently ($P > 0.13$) on the sandy loam site and loamy sites. In California, the microdistribution of this species was inversely correlated with light intensity (Pitts & Barbour 1979), which would suggest a preference for the sandy loam site in this current study.

Onychomys arenicola, the most-frequently trapped mammal in this study, is unevenly distributed in Trans-Pecos Texas, being common in desert habitats of the Guadalupe Mountains National Park but rare in other regions (Schmidly 1977). During this study, 67 specimens were collected; frequency of capture was similar ($P > 0.54$) on the two sites (Table 2).

Neotoma micropus was trapped more frequently ($P < 0.0001$) in the sandy loam site than on the loamy site (Table 2). Several houses (nests) constructed of sticks, cacti and other materials were found on the sandy loam site, and none on the relatively shrub-free loamy site. Prior studies suggest that this species is opportunistic in selecting its nesting sites (Thies & Caire 1990). Ederhoff (1971) found *N. albigena* more common than *N. micropus* in the yucca grasslands of the Franklin Mountains near El Paso, Texas (approximately 100 km to the northwest), yet no specimens of *N. albigena* were trapped during this study.

The sex ratio for *O. arenicola* was male-biased ($P < 0.05$) on the sandy loam site. The sex ratio for this species on the loamy site, and for *P. flavus* and *P. leucopus* on both sites, were not significantly different from 1:1 ($P > 0.05$). Body weights of males of these three species were greater on the sandy loam site than on the loamy site (Table 2).

Species associations, perhaps indicating common habitat preferences rather than interspecies affinities, were suggested by species that were collected at the same trap station. On the sandy loam site, *R. megalotis* co-occurred only with *O. arenicola*, and *R. montanus* co-occurred only

with *O. arenicola* and *P. leucopus*. *Onychomys arenicola* co-occurred with all other species except *D. ordii*. *Peromyscus leucopus* co-occurred with *P. maniculatus* and *N. micropus* on four and five different trap stations on the sandy loam site, respectively, while *P. flavus* was captured with *O. arenicola* on five different stations on the sandy loam site. At no single station were more than three species captured.

All except hibernating species were assumed to have been removed by the end of the fifth trapping session (15 January 1993). No specimens were captured at that time, or during the next trapping session (17 May). However, trap success for *P. flavus* reached a peak during the last trapping session (10-12 August), perhaps indicating that this species was inactive during the winter.

CONCLUSIONS

Almost twice as many rodents were trapped in a more densely vegetated sandy loam site than in a less densely vegetated loamy site in a Chihuahuan Desert grassland. Additionally, body weights of *P. flavus*, *P. leucopus* and *O. arenicola* were greater for individuals on the sandy loam site. Taller grass height and denser shrub cover on the sandy loam site are important habitat characteristics that may provide protective cover and food availability for desert rodents.

Trapping results in this desert grassland do not support published habitat descriptions for *Perognathus falcatus* (cf. Schmidly 1977) or *Dipodomys merriami* (cf. Rylander et al. 1991). Additionally, considerable numbers of *Reithrodontomys montanus* were trapped relative to reports in the literature.

Vegetation structural characteristics in Chihuahuan Desert grasslands appear to be important habitat components for rodents. In particular, although rodents in general appear more numerous in sandier habitats with deeper soil, taller grass cover and denser shrubs, habitat "preferences" often are species-specific. For example, *P. flavus* and *O. arenicola* were trapped with equal success in the sandy loam site and loamy site and *D. merriami* was trapped more frequently in the loamy site.

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THE EFFECTS OF FLOODING ON BOTTOMLAND HARDWOOD SEEDLINGS PLANTED ON LIGNITE MINE SPOIL IN EAST TEXAS

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Abstract.—Seedlings of five bottomland hardwood wetland species were planted in experimental wetlands constructed on lignite mine spoil in east Texas. First-year survival and timing of mortality were related to the flood tolerance of a given species. The order of survival regardless of flood treatments was: baldcypress (*Taxodium distichum*), overcup oak (*Quercus lyrata*), Nuttall oak (*Quercus nuttalli*), willow oak (*Quercus phellos*), and Shumard oak (*Quercus shumardii*). Hardwood species exhibited little growth, possibly because of nutrient limitations and flood stress. The low growth rates of bottomland hardwood seedlings planted on lignite mine spoil, the complexity of bottomland hardwood systems, the time required for bottomland hardwoods to reach maturity, and the long-term success of creation or restoration projects are also reviewed.

During the 1950's to 1970's bottomland hardwood (BLHW) wetlands suffered losses exceeding 120,000 ha per year (MacDonald et al. 1979; National Research Council 1982; Wilen & Frayer 1990). In Texas, over 60% of an original estimated 6.5 million ha of bottomland vegetation (i.e., western riparian and bottomland hardwoods) were lost by the 1980's, primarily due to conversion to agriculture and reservoir construction. Additional reservoir construction is expected to directly eliminate another 20% of east Texas bottomland hardwoods and degrade substantial acreage of the remainder (Frye 1986). Although forested wetlands are declining more slowly now (Tansey & Cost 1990), the magnitude of their decline, and of wetlands in general, prompted the Bush administration to issue a "no-net loss" wetland policy (Anonymous 1989) later endorsed by the Clinton administration (Anonymous 1993).

Surface-mining companies can assist in fulfilling this policy through wetland creation efforts because of regulatory requirements for soil stabilization, sediment retention, and treatment of mine drainage on reclaimed surface-mined lands (Nawrot & Klimstra 1989; Kepler 1990; Brenner 1992). In Texas, over 405,000 ha of land eventually will be surface-mined (Hossner 1980; McKnight 1992), thereby creating numerous opportunities for BLHW wetland creation. Techniques for

creating BLHW systems, however, are considered both inefficient and unpredictable (Clewel & Lea 1990), particularly on surface-mined lands where altered soil properties may affect growth and survival of BLHW species. Relative to soils from BLHW systems, mine spoil from east Texas is typically low in organic matter, highly compacted, and has poor soil structure (Dixon et al. 1980; Patrick 1981). There is a need for basic and applied research directed at the creation and restoration of BLHW wetlands on surface-mined lands.

The objectives of this study were to determine the effects of flooding on the growth and survival of seedlings of BLHW wetland species planted on lignite mine spoil in east Texas and develop management strategies for the creation and/or restoration of BLHW wetlands on surface-mined lands in east Texas.

STUDY AREA AND METHODS

The study was conducted in a series of nine experimental ponds constructed on 1-yr old lignite mine spoil on Texas Utilities' Big Brown Mine in Fairfield, Texas. Each experimental pond consisted of a shallow basin and a planting shelf that was approximately 12 m long and 2.5 m wide. A gravitational flow system connected each pond to a 0.5 ha reservoir.

Spoil material from this site is heterogeneous but generally is of intermediate texture and often approximates silty clay loams and clay loams (Dixon et al. 1980). Spoil was moderately acidic ($\text{pH} = 6.7 \pm 1.1$; $x \pm 1 SD$; $n = 18$) and low in nitrogen (N) (1.4 ± 0.6 ppm; $n = 18$), and depth of the water table was > 30 cm during drawdown. Due to the low nitrogen levels, the shelves of the experimental ponds were fertilized with 112 kg/ha of 30-10-0 fertilizer in April 1991. Preliminary flooding experiments indicated that three ponds had significant leakage; therefore, bentonite clay was added in summer 1991 to seal the shallow basins within these ponds.

Five species were chosen for study based upon flooding tolerance (Hook 1984) and wildlife value. In order of decreasing flood tolerance the species were: baldcypress (*Taxodium distichum*), overcup oak (*Quercus lyrata*), Nuttall oak (*Q. nuttalli*), willow oak (*Q. phellos*), and Shumard oak (*Q. shumardii*). Bare-root seedlings were obtained from a commercial nursery located in Leland, Mississippi, where they were grown from locally collected seeds. Seedlings were placed in cold storage for one month prior to planting.

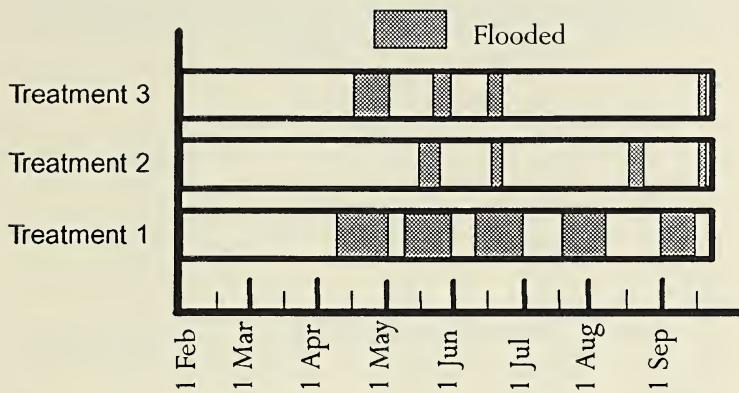


Figure 1. Experimental flooding regimes (from February 1992 through September 1992) used to test the effects of flooding on seedling growth and survival of bottomland hardwood wetland species planted on lignite mine spoil. Ponds were flooded 5-10 cm deep according to their designated schedule except for rare one- to three-day deviations. Seedlings were planted on 7 February 1992.

On 7 February 1992, 25 seedlings of each species were planted on the shelf of each experimental pond ($n = 225$ per species). To ensure maximum dispersion (Hurlbert 1984) and to prevent clumping of seedlings on highly acidic microsites (Arora et al. 1980), each shelf was divided into five square blocks each consisting of five seedlings of each species randomly placed at 0.5 m intervals.

Three experimental flooding regimes were designed to test the effects of flooding on seedling growth and survival (Figure 1). Treatment 1 contained five flooding episodes of long duration (≥ 15 days each) with the initial flooding episode occurring in early spring (10 April). Treatments 2 and 3 each consisted of four flooding episodes ≤ 16 days each; however, the initial flooding episode of treatment 3 was longer (16 days vs 10 days) and earlier in the spring (16 April vs 14 May) than the initial flood period of treatment 2. Flooding regimes were equally and randomly replicated among the nine ponds (i.e., 3 replicates/flood trt). Seedlings were not flooded until April to allow time for root establishment. Ponds were flooded approximately 5-10 cm deep according to their designated schedule except for rare one- to three-day deviations. Following drawdown, the upper 5 cm of soil remained saturated < 5 days.

Seedling survival was monitored every 7 to 10 days. Height from the ground to the highest point of the stem with a living leaf was measured

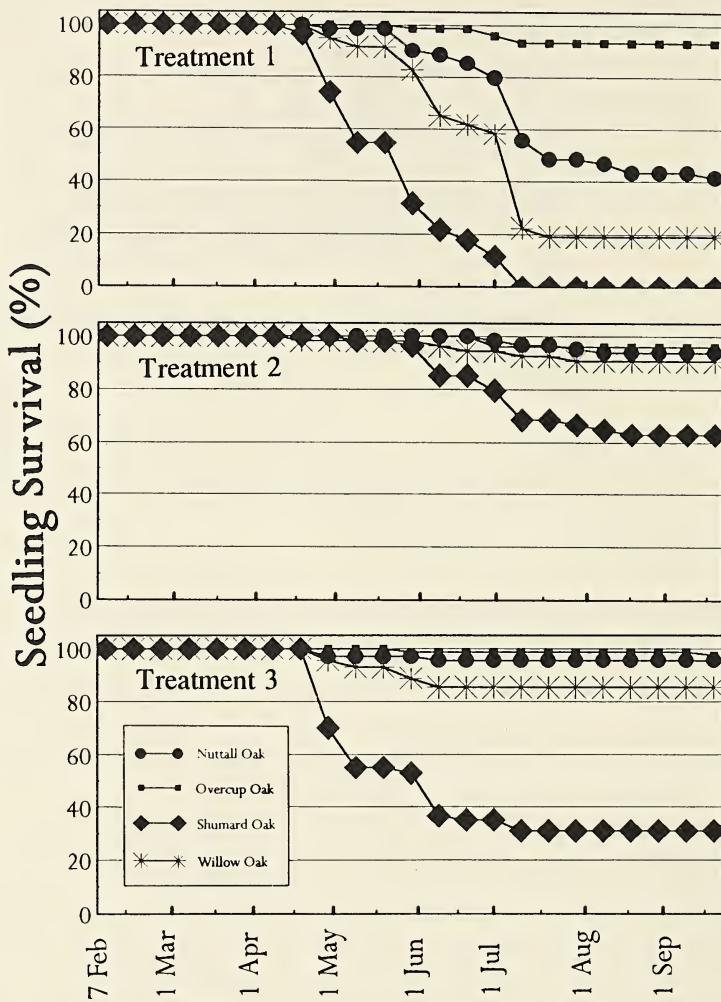


Figure 2. The effects of three experimental flooding regimes (from February 1992 through September 1992) on first-year seedling survival of four bottomland hardwood species planted on lignite mine spoil. Survival of baldcypress was 100% in all treatments.

on 7 February, 12 May, 20 July, and 25 September. Survival data were analyzed with a fixed-effects analysis of variance; preplanned contrasts (Freund & Wilson 1993) were used to compare treatment and species differences. Analysis of covariance (Lentner & Bishop 1986) was used to determine treatment effects on height growth with initial height as the covariate.

Table 1. Between-species comparisons of treatment effects on mean first-year seedling survival of bottomland hardwood wetland species planted in experimental ponds on Texas Utilities' Big Brown Mine, Fairfield, Texas, 1992.

Treatment	Taxon	Mean Percent Survival	(SE)	*	n
1	baldcypress	100.0%	(0.0)	A	(68)
	Nuttall oak	41.4%	(11.6)	B	(57)
	overcup oak	93.2%	(2.8)	A	(74)
	Shumard oak	0.0%	(0.0)	C	(58)
	willow oak	19.1%	(16.8)	BC	(58)
2	baldcypress	100.0%	(0.0)	A	(75)
	Nuttall oak	93.9%	(1.7)	A	(66)
	overcup oak	100.0%	(0.0)	A	(74)
	Shumard oak	63.0%	(20.9)	B	(61)
	willow oak	90.7%	(4.9)	AB	(61)
3	baldcypress	100.0%	(0.0)	A	(74)
	Nuttall oak	95.5%	(4.5)	A	(67)
	overcup oak	97.5%	(1.3)	A	(78)
	Shumard oak	31.0%	(16.2)	B	(51)
	willow oak	85.3%	(5.0)	A	(50)

* Means sharing a letter within the same treatment do not differ ($P > 0.05$).

n Represents the total number of seedlings alive at the initiation of the study (April 1991) from a total of 75 seedlings/species/treatment planted in February 1991.

RESULTS

Final survival and the timing of mortality were related to the flood tolerance of a given species. The order of highest to lowest survival was baldcypress, overcup oak, Nuttall oak, willow oak, and Shumard oak in all treatments except treatment 2, where both baldcypress and overcup oak had 100% survival (Table 1 and Figure 2). Baldcypress also exhibited 100% survival in treatments 1 and 3, whereas overcup oak survival exceeded 93% and did not differ significantly ($P > .05$) from baldcypress in any treatment.

With the exception of Shumard oak, survival of all species was $\geq 90\%$ in treatment 2 and $\geq 85\%$ in treatment 3. Survival did not differ ($P > .05$) between these treatments for any species. However, Shumard oak seedlings demonstrated lower survival and three to four times greater variability in survival than most other species in these treatments.

The lowest survival rates of all hardwood species were in treatment 1 (Table 1). Shumard oak (0% survival) was unable to tolerate the frequent and prolonged flooding conditions of treatment 1. Willow oak exhibited a mean survival rate of 20% which was not significantly ($P >$

.05) different from that of Shumard oak. In addition, the variability of willow oak survival was exceedingly high with the standard error almost as large as the mean ($\bar{x} = 19.1$; $SE = 16.8$).

The relationship between the flood tolerance of a given species and the timing of mortality was most visible in treatment 1. Survival of Shumard oak dropped to < 80% following the first 22 day flooding period (10 April to 1 May) and dropped to < 30% following the next flooding period (8 May to 31 May) (Figure 2). In contrast, the more water-tolerant willow oak exhibited > 90% survival following the first flooding period, 65% following the second flooding period, and 20% after the third flooding period. Survival of Nuttall oak equaled willow oak after the second flooding episode (65%), but unlike willow oak which experienced further declines, Nuttall oak survival remained relatively constant for the rest of the study.

Analysis of covariance indicated that first-year growth rates were significantly related to initial height ($f = 12.5$; $P = .0096$; $df = 1$), species ($f = 6.63$; $P = .0157$; $df = 4$), and treatment-species interactions ($f = 3.71$; $P = .0006$; $df = 7$). Baldcypress exhibited significantly ($\alpha < .05$) greater growth than the hardwood species in all treatments, with the exception of Shumard oak in treatment 2 (Table 2). Baldcypress growth was significantly greater in treatment 1 than in treatments 2 and 3, but no other treatment differences were observed for any species. Low growth rates were common for the hardwood species. Leaf abscission often resulted in negative growth rates since height was measured from the ground to the highest point of the stem with a living leaf. No consistent differences among the hardwood species were observed within treatments.

DISCUSSION AND CONCLUSIONS

This study indicates the importance of hydroperiod in regulating growth and survival of BLHW seedlings. Furthermore, the results of this study and others (Gorsira & Risenhoover 1994; Holl & Cairns 1994) suggest that the potentially slow growth rates of BLHW seedlings planted on lignite mine spoil, the complexity of BLHW systems, and the time required to reach maturity even under more favorable conditions (Walbridge 1993) pose significant problems to creation and restoration efforts on surface-mined lands (Gorsira & Risenhoover 1994; King 1994).

The consistent trend within the rank-order of survival suggested that

Table 2. Between-species comparisons of treatment effects on mean first-year height growth of seedlings of bottomland hardwood wetland species planted in experimental ponds on Texas Utilities' Big Brown Mine, Fairfield, Texas, 1992.

Treatment	Taxon	Height Growth	(SE)	*	n
1	baldcypress	16.5 cm	(1.3)	A	(68)
	Nuttall oak	- 0.6 cm	(2.1)	C	(23)
	overcup oak	4.9 cm	(1.2)	B	(69)
	Shumard oak	—	—	—	—
	willow oak	3.4 cm	(3.0)	BC	(11)
2	baldcypress	8.5 cm	(1.2)	A	(75)
	Nuttall oak	3.0 cm	(1.3)	B	(62)
	overcup oak	4.9 cm	(1.1)	B	(74)
	Shumard oak	5.4 cm	(1.6)	AB	(41)
	willow oak	- 2.1 cm	(1.3)	C	(56)
3	baldcypress	10.4 cm	(1.2)	A	(74)
	Nuttall oak	1.0 cm	(1.3)	C	(64)
	overcup oak	5.6 cm	(1.1)	B	(76)
	Shumard oak	0.7 cm	(2.4)	BC	(17)
	willow oak	- 1.0 cm	(1.5)	C	(43)

* Means sharing a letter within the same treatment do not differ ($P > .05$).

n Represents the total number of seedlings surviving the treatment.

all flooding regimes used in this study were of relatively long duration for the less water-tolerant species. This was particularly true for Shumard oak, which did not exceed 63% survival in any treatment. Other studies also reported that Shumard oak is weakly water tolerant and that prolonged flooding can cause substantial mortality (Hosner 1960; Krinard & Johnson 1981).

The generally low growth rates of all hardwood species may have been related to factors such as flood-stress and nutrient limitations. Several studies note that growth of BLHW is sensitive to soil moisture and nutrient levels (Kennedy 1970; Harms 1973). Soil analyses in fall 1992 indicated that soil N was extremely low (≤ 1.0 ppm; $n = 13$) in all ponds. A lack of N can inhibit growth and/or result in the allocation of the available N to the root system at the expense of the shoots, thereby reducing height growth (Dickson & Broyer 1972). Low soil pH, such as that associated with surface-mining operations in other regions of the United States (Williston & LaFayette 1978) can alter the availability and uptake of nutrients (Haines & Carlson 1989) and thereby limit tree growth. The soil pH observed in this study, however, falls within the preferred ranges of the test species (Williston & LaFayette 1978) and presumably did not affect seedling growth and survival.

Created BLHW wetlands will require a considerable period of time before they can begin to replace the values associated with most natural stands (Walbridge 1993; King 1994). Gorsira & Risenhoover (1994) noted that reclaimed woodlots on Big Brown Mine will require at least 27 yr before vertical structure, canopy closure, and other habitat features resemble those of non-mined woodlots. Permitting agencies should, therefore, carefully review applications for permits to impact BLHW wetlands and should demand long-term commitments (≥ 25 yr) to insure successful mitigation through BLHW creation or restoration. Mitigation banks may provide a plausible alternative (Hammer et al. 1994). When feasible, reclamation officials should be granted the flexibility to experiment with BLHW wetland creation techniques in the normal reclamation process (Klimstra & Nawrot 1985).

The long-term success of a creation or restoration project will necessitate designing areas so that the mean and variation of the duration, frequency, depth, and timing of flooding at each point in the floodplain can be determined with a high level of confidence, thereby enabling species to be planted at the appropriate point along the flood gradient. Securing soils from existing BLHW wetland areas also may increase the probability of success of BLHW wetland creation on surface-mined lands. Added soils can enhance the establishment of understory vegetation that can increase the vertical structure and plant diversity of the wetland site and provide substrate stabilization if mass mortality of seedlings occurs (Clewell 1988; Brenner & Hofius 1990; Brenner 1992, Gorsira & Risenhoover 1994). Furthermore, the higher organic matter and nutrient content of BLHW wetland soils (Patrick 1981) as compared to lignite mine spoil (Dixon et al. 1980) may improve growth rates and survival of planted seedlings.

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GENERAL NOTE

DATE OF BIRTH, LITTER AND NEONATE SIZE OF A
DIAMONDBACK WATER SNAKE, *NERODIA RHOMBIFER*,
FROM SOUTHERNMOST TEXAS**Frank W. Judd and Martin Bray***Department of Biology, University of Texas-Pan American, Edinburg, Texas 78539
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Reports of the time of birth of the diamondback water snake, *Nerodia rhombifer*, place the beginning of litter production in August (Wright & Wright 1957; Collins 1974; Tennant 1985; Dundee & Rossman 1989). Ford et al. (1990) report litters from northeastern Texas on 17, 20 and 23 August. During the course of live-trapping *N. rhombifer* for a study of pesticide contamination at Santa Ana National Wildlife Refuge, Hidalgo County, Texas, a female (SVL 1.15 m, wt 2.3 kg) was captured during the night of 20 July 1995 and held in the laboratory for blood sampling. This female gave birth to a litter of 39 offspring on 21 July 1995. This date of birth is the earliest known record for the species. During the night of 20 July 1995 neonates were observed at Willow Lake within the Santa Ana National Wildlife Refuge, so the birth in captivity is not considered an isolated event.

Three of the 39 neonates were either born dead or died before they were measured. Mean snout-vent length (SVL) of all 39 neonates was 228 mm (range 202-240, $SD = 9.6$, $CV = 4.2$). This is significantly smaller ($P < .01$, 523 df) than the mean of 246.1 mm ($SE = 0.6$) reported by Plummer (1992) for 486 neonates from Arkansas. Ford et al. (1990) reported a mean SVL of 214.8 mm for 55 neonates (two litters) from northeastern Texas. The neonates from southernmost Texas were significantly larger ($t = 8.57$, 92 df , $P < .001$) than the neonates from northeastern Texas. Aldridge et al. (1995) reported a mean SVL of 213 mm (range 204-221) for neonates from Veracruz, Mexico, but did not give a sample size or a measure of variance. Consequently, a statistical comparison of neonate SVL of these specimens is not possible.

The data reported here are the first available for a subtropical population of *N. rhombifer*. The information on geographic variation in litter size suggests that there is no clinal latitudinal variation in neonate size in *N. rhombifer*.

The litter size (39) observed in this study is beyond the range (8-36) reported for *N. rhombifer* from Veracruz, Mexico, (Aldridge et al. 1995) and it is larger than the litter sizes of 26, 33, and 37 reported by Ford et al. (1990) for three litters from northeastern Texas. Conversely, it is within the ranges reported by Cagle (1937) for Tennessee (13-42) and Plummer (1992) for Arkansas (12-48). Aldridge et al. (1995) reported that clutch size was significantly smaller in the tropical Veracruz, Mexico, population than in temperate populations. While caution should be used in drawing inferences based on the meager data currently available for Texas populations, it appears that litter size in *N. rhombifer* from southernmost Texas may be typical of that of temperate populations and significantly larger than that of tropical populations.

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BOOK REVIEW

Catalog of Vertebrates of the Concho Valley Region of Texas by Terry C. Maxwell. Wm. C. Brown Publishers, 1996, First Edition, 111 pages, selected references, indices. ISBN 0-697-33608-5.

The stated purpose of this catalog is to provide a list of vertebrate species of the Concho Valley of Texas for use by naturalists, scientists, students, teachers and government agencies. The author achieves his purpose in fine fashion. Based on our collective knowledge, this appears to be a thorough and reliable catalog. The catalog lists 54 extant species of fishes, 16 amphibian species from the area (one salamander, 14 anurans), 68 species of reptiles (9 turtles, 22 lizards, 47 snakes), 353 bird species and 63 mammal species.

Comments for some of the species provide clarifications of taxonomy and distribution although there is a considerable greater emphasis on birds and mammals than fishes, amphibians and reptiles, perhaps due to the interests and research concentration of the author. For example, 13% of the fishes have substantive comments along with their listing, while nearly one-quarter of the birds and about one-third of the mammals receive such annotated comments. The lists of hypothetical, peripheral and erroneous species and the explanations accompanying these species may prove to be the most useful parts of the catalog for they contain difficult to find information that is not readily available in books covering broader areas.

The text of the catalog is run end-to-end. This saves space but it is less effective in emphasizing major taxonomic groups. Indeed, Classes begin in the middle of a page (Amphibia) or toward the end of a page (Mammalia) in some cases. Orders and Families may be orphans at the ends of the pages.

Mistakes are few; unfortunately, some are striking. For example, the catalog is divided into major sections using Roman numerals. There are two V's. Erroneous Species should be VI and Erroneous is misspelled. Other typos are infrequently encountered, such as the misspelling of Conifer on page 2. The redbreast sunfish (*Lepomis auritus*) is not listed as introduced, an error that is quite common even among fisheries workers. The suggestion on page 65 that Sennett's Hooded Oriole (*Icterus cucullatus sennetti*), is probable in the Concho Valley area may

need to be amended or justified. The Mexican Hooded Oriole (*Icterus cucullatus cucullatus*), is the subspecies of the Hooded Oriole shown by Oberholser (The bird life of Texas, Vol. 2, 1974) to occur in the Eagle Pass/Del Rio area and *I. cucullatus sennetti* occurs only south of Laredo and Kingsville.

In general, the value of catalogs like this might be greatly increased if information on seasonal occurrence, habitat preference and abundance had been presented. For example, how common are Broad-billed Hummingbirds and White-throated Swifts in the region, as opposed to Black-chinned Hummingbirds and Chimney Swifts? Similar information would also be desirable for the other taxonomic groups. Although not a goal of this catalog, presentation of at least a brief status report for each species would have greatly enhanced its value to the intended users.

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Smith, J. D., & G. L. Davis. 1985. Bats of the Yucatan Peninsula. Occas. Pap. Mus., Texas Tech Univ., 97:1-36.

Books.—

- Jones, T. L. 1975. An introduction to the study of plants. John Wiley & Sons, New York, xx+386 pp.
Jones, T. L., A. L. Bain & E. C. Burns. 1976. Grasses of Texas. Pp. 205-265, in Native grasses of North America (R. R. Dunn, ed.), Univ. Texas Studies, 205:xx+1-630.

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- Davis, G. L. 1975. The mammals of the Mexican state of Yucatan. Unpublished Ph.D. dissertation, Texas Tech Univ., Lubbock, 396 pp.

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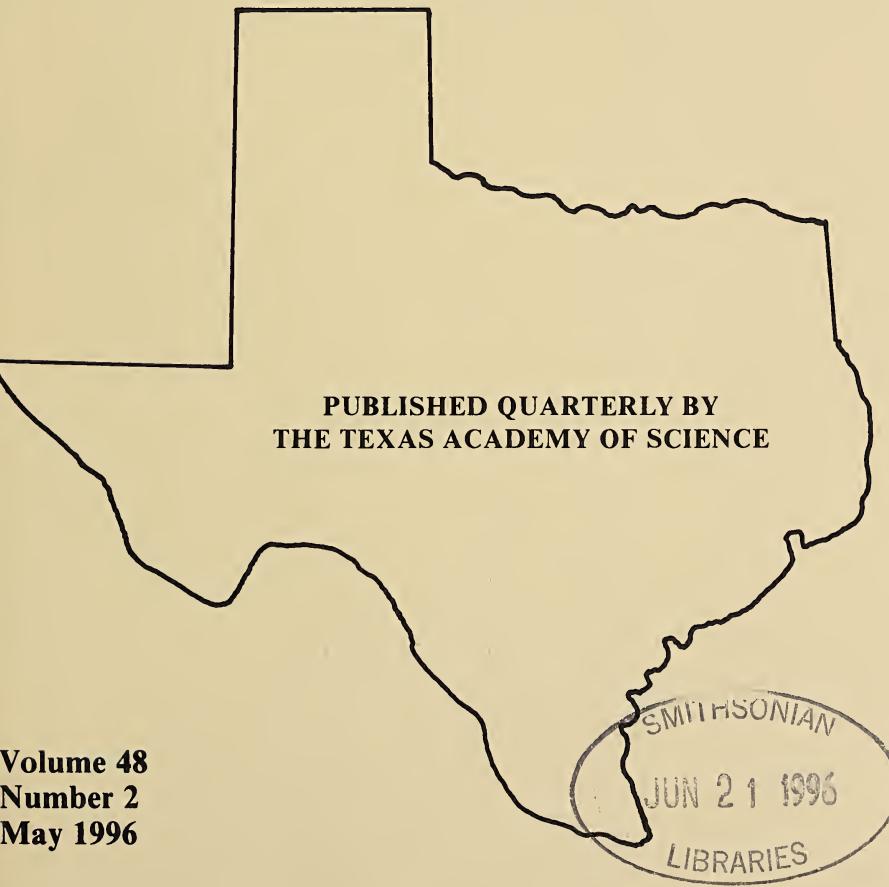
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A NEW CONODONT FROM THE UPPERMOST LAMAR LIMESTONE OF THE DELAWARE BASIN OF WEST TEXAS

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Abstract.—*Clarkina crofti* is described from the deepwater pelagic facies of the uppermost Lamar Limestone of the Delaware Basin of west Texas. This new species of conodont is characterized by the presence of a reduced platform. This feature is considered ancestral to the evolutionary line that gave rise to the genus *Neospathodus* which is characterized by the absence of a platform. *Clarkina crofti* appears to exhibit a high potential for the correlation of the post-Lamar/pre-Castile level of the Guadalupian type area with deepwater deposits of Tethys origin.

A new species of *Clarkina* from the uppermost Lamar Limestone of the Delaware Basin is herein described. It is an immigrant from a deepwater pelagic fauna that has evolved outside the Delaware Basin, so it has high potential for correlation with the Tethyan Permian deepwater pelagic faunas, such as those found in western Sicily. Prior investigations and/or reviews of conodonts from west Texas include those of Druce (1973), Babcock (1976) and Clark & Behnken (1979).

Clarkina Kozur 1990b

Type species.—*Gondolella leveni* Kozur & Mostler 1976.

Clarkina leveni (Kozur & Mostler 1976).—Kozur 1990b.

Remarks.—Kozur (1990b) established this genus for conodonts exhibiting a gondolellid apparatus in which the platform elements display a subterminal pit, marginal ridges on the otherwise flat keel, and a distinct free blade. With respect to this feature, these forms are similar to *Neogondolella* Bender & Stoppel and especially to *Paragondolella* Mosher, which are both believed to have evolved from platform-less ancestors of the genus *Neospathodus* Mosher. Transitional forms from *Neospathodus* to *Paragondolella* are known in the basal Olenekian and from *Neospathodus* to *Neogondolella* in the latest Olenekian and basal Anisian (Kozur 1990a; 1990b).

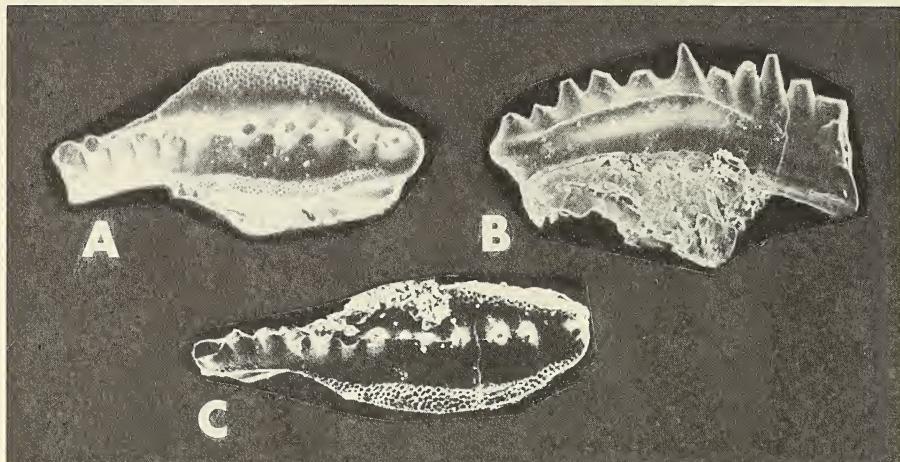


Figure 1. *Clarkina crofti* n. sp., sample 243, uppermost Lamar Limestone, 0.40 m below its top, outcrop about 1 km east of locality H of Ormiston and Babcock (1979), Delaware Basin. A-B, Holotype (MNA N 4065) with partially preserved basal body, upper view (A) and lateral view (B). C, Paratype (MNA N 4066), upper view, x100.

Clarkina crofti, new species
(Figure 1)

Neogondolella sp.—Croft 1978 (unpublished), p. 51-52, pl. 5, figs. 1-10. *Editor's note*.—The specific epithet proposed by Croft constitutes a *nomen nudum* and is not published here in compliance with the proposal by Mayr & Ashlock (1991:391).

Clarkina cf. *bitteri*.—Kozur 1992d, figs. 1b/17a, b.

Type material.—Holotype (N 4065) and paratype (N 4066) deposited with the holdings of the Museum of Northern Arizona at Flagstaff, Arizona, U.S.A.

Type locality.—Outcrop approximately 1 km E of locality H of Ormiston & Babcock (1979), Culberson County, Texas.

Type horizon.—Sample 243, uppermost Lamar Limestone, 40 cm below its upper surface.

Etymology.—In honor of Dr. J. S. Croft, who first discovered and reported this new taxon.

Diagnosis.—*Clarkina* with long free blade, narrow platform with strongly upturned margins along the posterior two-thirds of the platform element, which is also mostly rudimentary at the posterior end. Carina high, lowest in the posterior part.

Description.—Platform element small, moderately arched, straight or laterally slightly bent. The platform is strongly reduced and extends only along the posterior two-thirds of the unit. In some specimens the platform is rudimentary throughout its length. The platform is narrow even in its widest part behind the midlength or at the beginning of the posterior third of the unit. Near the posterior end the platform width is distinctly reduced. The free blade is very long and comprises the anterior third of the unit. Along its anterior part no platform rudiments are present, along its posterior part very narrow, ridge-like platform rudiments are present. The platform margins are strongly upturned and display honeycomb microreticulations. No serration is present. Basal cavity subterminal, in forms with strongly reduced platform nearly terminal. Keel narrow. Carina high, with long, unfused denticles. The height of the carina decreases slowly toward the posterior end. All denticles are nearly straight or only slightly inclined.

Occurrence.—Rare in the topmost Lamar but, according to Croft (1978), dominant in the basal Castile Formation at the very base of the Ochoan below the base of the hypersaline facies. Samples examined during this study of the basal Castile "papery limestone" of the Delaware Basin and of the facially and time-equivalent "papery limestone" of the basal Tessey Formation in the Glass Mountains have not yielded any conodonts. In turn, a first dissolving of a post-Lamar/pre-Castile limestone from the Lamar Cuesta near locality N of Ormiston & Babcock (1979) immediately west of Texas Ranch Road 1108, Culberson County, Texas, has yielded a few broken specimens of *Clarkina crofti*. This limestone has the same stratigraphic position as the basal "Castile Limestone" sensu Croft (1978) that he sampled near our locality on the Lamar Cuesta at the opposite, eastern side of Texas Ranch Road 1108. The specimens of Croft (1978) are therefore not from the basal Castile, but from a post-Lamar/pre-Castile limestone intercalation (post-Lamar Bell Canyon Formation).

Remarks.—The material illustrated by Croft (1978) included some specimens with strongly reduced platforms that consist only of a broadened ridge. These specimens are already very similar to Early Triassic through basal Anisian genera in the transitional field from platform-bearing gondolellids to the blade-like *Neospathodus* and vice versa: *Kashmirella* Budirov, Sudar & Gupta, the transitional genus from *Clarkina* to *Neospathodus*, *Chengyuania* Kozur (1994), the transitional genus from *Neospathodus* to *Paragondolella* and *Chiosella* Kozur, the transitional genus from *Neospathodus* to *Neogondolella*.

DISCUSSION

Conodonts are stratigraphically one of the most important fossil groups in the Permian. They evolved rapidly and, in some stratigraphic intervals, even somewhat more rapidly than Permian ammonoids. Conodonts also exhibit a broader distribution than Permian ammonoids because they are the only stratigraphically important Permian fossil group that is little affected by provincialism. Such provincialism is very strong among all other stratigraphically important Permian fossil groups, especially fusulinids. Boreal and Tethyan ammonoids are also very different from one another.

As with other geological systems, Permian conodont distribution has been influenced by facies differences. Shallow water and pelagic conodont faunas are rather different, but in many places, especially in widespread slope deposits, both shallow water and pelagic conodonts occur in the same rocks. Moreover, some genera, and even some species, occur both in shallow water (except intratidal deposits) and pelagic deposits. Therefore, the correlation of shallow water and pelagic conodont zonation is generally very easy.

The evolutionary rates of shallow-water conodonts of the Lower Permian are considerably more rapid than those of pelagic conodonts. This is considered an exceptional situation in conodont evolution. Lower Permian shallow-water conodont zonation is therefore more detailed than pelagic zonation. During the Upper Permian, the evolutionary rates of both shallow water and pelagic conodonts were rapid; detailed zonations of shallow water and pelagic conodonts have been established. With the exception of the Roadian stage, the shallow-water conodonts of the Middle Permian are currently considered of minor importance relative to conodont biostratigraphy because it is based on the evolution of pelagic conodonts. The development from the serrated *Mesogondolella postserrata* (Clark & Behnken) through *Mesogondolella shannoni* Wardlaw into the unserrated *Clarkina altudaensis* Kozur within the uppermost Altuda Formation of the Glass Mountains at the southern margin of the Delaware Basin (Kozur 1991; 1992b; 1992c; 1992d) can also be found in South China (Jin et al. 1993), allowing the exact correlation of the upper boundary of the Capitanian (and by this of the upper boundary of the Middle Permian Guadalupian Series) with the Tethyan scale as established in South China.

As Kozur (1990b) pointed out, *Clarkina* evolved from *Mesogondolella*

by slight forward-shifting of the terminal basal cavity (*Mesogondolella*) into a subterminal position (*Clarkina* and most of the stratigraphically younger gondolellids), by a change of the shallow trough-like surface into a flat lower surface of the keel with low narrow marginal ridge, and by the development of a free blade and disappearance of the platform serration (only in serrated *Mesogondolella*). This development occurred in several lineages within the genus *Mesogondolella*. The *Clarkina* features developed within the different lineages at slightly different times during the late Guadalupian or at the end of the Guadalupian (Capitanian/Dzhulfian or Wuchiapingian boundary). Kozur (1990b) noted that *Clarkina bitteri* (Kozur) is the oldest *Clarkina* and the forerunner of the main stock within this genus (*C. bitteri* / *C. leveni* lineage). A second important lineage leads from serrated *Mesogondolella postserrata* through serrated *M. shannoni* to unserrated *Clarkina altudaensis*. This short-lived species is the forerunner of *Clarkina changxingensis* (Wang & Wang) that evolved soon after the appearance of *C. altudaensis*. *Clarkina changxingensis* is one of the most common conodonts of the Lopingian (Late Permian) Series (Kozur 1992a). A third lineage, important especially for the Boreal realm, leads from serrated *Mesogondolella behnkeni* (Bando et al.) to unserrated *Clarkina rosenkrantzi* (Bender & Stoppel).

Jin et al. (1993) expressed a different view, restricting *Clarkina* to the *C. bitteri/C. leveni* lineage and leaving other *Clarkina*, which had not evolved from *C. bitteri*, within the genus *Mesogondolella*. By this, no form separation between *Mesogondolella* and *Clarkina* is possible. This is best documented by *Clarkina changxingensis*, which is regarded by many Chinese authors as a subspecies of *Clarkina subcarinata* (Sweet), a characteristic species of the *C. bitteri/C. leveni* stock. *Clarkina changxingensis*, however, evolved in the uppermost Altuda Formation from *C. altudaensis*. All transitional forms from *C. altudaensis* to *C. changxingensis* are present (Kozur 1992a; 1994). The development of one genus from another genus does not necessarily go through one species. As the example of *Mesogondolella/Clarkina* shows, several species of one genus may evolve the same new features that lead to the separation of a new genus. Examples for this mode of evolution are known also from other fossil groups (e.g., ostracods). Likewise, new families or higher taxonomic categories evolved often by changes of suprageneric features in several genera of the forerunner family. For instance, the characteristic features of the recent Punciacea (Ostracoda), like bracket teeth, narrow mesoplate, calcified inner lamella, and special

sculpture elements such as the pseudofrill, evolved independently from each other in different lineages of the latest Permian Kirkbyacea, the forerunners of the Punciacea (Kozur 1993b).

For the first time a strong platform reduction can be observed in *Clarkina* that lead to the development of the blade-like platform-less *Neospathodus* during the basal Triassic. The platform reduction is an iterative development within gondolellid conodonts that occurs in different lineages at different times (Kozur 1990b). Despite the strong platform reduction, *C. crofti* is probably not the direct forerunner of *Neospathodus*, which begins only in the Gandarian substage (= Dienerian) of the Brahmanian stage (= Induan stage, the original Induan comprises also the lower substage of the Olenekian) (Kozur 1992e). However, it shows for the first time the trend of platform reduction within *Clarkina* that lead ultimately through transitional forms to *Neospathodus* in the Lower Triassic.

Clarkina crofti does not belong to the *Mesogondolella serrata/M. postserrata* lineage of the Delaware Basin and its slopes, but to the *C. bitteri* group. *Clarkina bitteri* displays also a distinct free blade with rapid narrowing of the platform at the beginning of the free blade, but the platform is not reduced, but wide, so it has a different outline.

The only similar older species from the Delaware Basin is *Mesogondolella* (?) *denticulata* (Clark & Behnken). According to Wardlaw (pers. comm.), "Neogondolella" *denticulata* is a junior synonym of *Mesogondolella postserrata* (Behnken). This study agrees with Wardlaw (pers. comm.) in that, with the exception of the holotype, all "N." *denticulata* illustrated by Clark & Behnken (1979) are typical *Mesogondolella postserrata*. The holotype, however, is a form with a strongly upturned margin, distinct free blade and very high carina. It appears to be an independent species. The strongly upturned margin argues against a close relationship to the serrated *Mesogondolella* of the *M. nankingensis*/ *M. postserrata* group. The presence or absence of serration in the holotype is not clear from the oblique lateral view. On one side, where the upper surface is seen, no serration of the anterior platform can be observed. On the other side, shallow vertical furrows are present on the lower outer side of the anterior platform. This may indicate the presence of serration on the platform surface, but such shallow vertical furrows on the lower outer side of the platform are also common in unserrated Late Permian and Triassic gondolellids. If the holotype of *Mesogondolella* (?) *denticulata* is unserrated, it could be

related to *Clarkina crofti*, but is easily distinguished from this species. With the exception of the anteriormost part, a distinct platform extends along the free blade and the platform width is unreduced near the posterior end of the unit. Moreover, the height of the carina does not decrease toward the posterior end. The sudden appearance of *C. crofti* in the deep-basin parts of the uppermost Lamar and its dominance in the post-Lamar/pre-Castile Bell Canyon Formation of the same facies indicate immigration from outside the Delaware Basin.

PALEOECOLOGY AND BIOSTRATIGRAPHY

Clarkina crofti occurs only in the deep-basin facies of the Lamar and post-Lamar/pre-Castile Bell Canyon Formation limestones. Its westernmost occurrence is about 1 km E of locality H, about 12 km E of the Capitanian reef margin. The water depth there was below 500 m. In the post-Lamar/pre-Castile limestones it was only found still further in the basin center. It is missing in the contemporaneous shallow pelagic uppermost Altuda Formation. In these beds only *C. altudaensis* occurs, at first still accompanied by *M. shannoni*, transitional forms between both species, and *Clarkina wilcoxi* (Clark & Behnken). In the topmost 20 cm of the Altuda, only *Clarkina lanceolata* (Ding), a late Wuchiapingian guideform, has been discovered. The fauna of the uppermost Altuda at the investigated localities (Kozur 1992b; 1992c) indicates water depth of about 50-100 m.

In the uppermost Lamar, *C. crofti* is accompanied by the last very rare *Mesogondolella shannoni* which is considered transitional to *Clarkina altudaensis*. In the rather thin (about 2-3 m thick) deep basinal post-Lamar/pre-Castile deposits along the Lamar Cuesta near the Texas Ranch Road 1108 so far only *C. crofti* and two specimens of *C. altudaensis* have been found by Croft (1978) and in material examined during this study. *Clarkina shannoni* is no longer present. Therefore, these beds can be easily correlated with the *C. altudaensis* zone of the uppermost Altuda in the Glass Mountains. However, the conodont fauna is rather different for facial reasons. Whereas the uppermost Altuda is dominated by *C. altudaensis*, which in several samples is the only gondolellid conodont, the deep-basin facies equivalents in the post-Lamar/pre-Castile interval are dominated by *C. crofti*, and *C. altudaensis* is only very subordinate.

As in the Delaware Basin, in the Tethyan realm a strong radiation of the *Clarkina bitteri* group can be observed within the Late Permian

Lopingian Series. Species of this lineage are the index species of the latest Permian pelagic zones within the Tethys (Teichert et al. 1973; Kozur 1978; 1989; 1990a; 1990b; 1990c; 1993a; Wang & Wang 1979; Nestell & Wardlaw 1987; Clark & Wang 1988; Jin et al. 1993).

Both the shallow pelagic *C. altudaensis* fauna and the deep pelagic *C. crofti* fauna are very different from the *Mesogondolella* faunas of the Middle Permian Guadalupian Series that are characterized by serrated *Mesogondolella* of the *M. nankingensis* / *M. postserrata* group. During the Early and Late Permian, in turn, only smooth gondolellids are present. The base of the Guadalupian Series has been defined by the first appearance of the serrated *M. nankingensis*. The sudden and world-wide disappearance of this group within phylogenetic lineages (*Mesogondolella shannoni* / *Clarkina altudaensis*, *Mesogondolella behnkeni* / *Clarkina rosenkrantzi*) is a first order event in conodont evolution and would be an ideal boundary between the Guadalupian and Lopingian Series in conodont stratigraphy, independent from the question of whether *C. altudaensis* and *C. rosenkrantzi* are smooth *Mesogondolella*, as Jin et al. (1993) assumed or *Clarkina* species as Kozur (1992b, 1992c, 1992d) assumed. Jin et al. (1993) found the same sudden disappearance of serrated *Mesogondolella* in the *M. postserrata* / *M. shannoni* / *Clarkina altudaensis* lineage in China as Kozur (1991, 1992b, 1992c, 1992d) found in the Altuda Formation at the margin of the Delaware Basin. Thus, the sudden disappearance of serrated *Mesogondolella* is not a local event in the Delaware Basin, which could be facies-controlled. For this reason, this study cannot confirm the proposal of Jin et al. (1993) that rapid change from the ribbed *Mesogondolella postserrata* (in their taxonomy including the similarly ribbed *M. shannoni*) into the unribbed *Clarkina altudaensis* should not be regarded as a natural boundary because it does not reflect any evolutionary event in geological and biological development from the Guadalupian to Lopingian.

An evolutionary event must not necessarily reflect the change from one genus to another (as in the interpretation of the lineage by Kozur 1992b; 1992c; 1992d). It can be also defined within a genus (as preferred by Jin et al. 1993). This does not mean, however, that it is not a biological event. The development from the unribbed *Mesogondolella idahoensis* (Youngquist, Hawley & Miller) to the ribbed *M. nankingensis* (Ching) is likewise placed within one genus, and there is now a general agreement that this world-wide traceable event is the best marker for the base of the Guadalupian Series (Glenister et al.

1993). Why shouldn't the likewise rapid and world-wide recognizable disappearance of the ribbed *Mesogondolella* be a biological event from the Guadalupian to the Lopingian Series? This statement would seemingly only "prove" that *Clarkina altudaensis* is a *Mesogondolella*, but would not change the fact that the serrated species of *Mesogondolella* appeared at the base of the Guadalupian and disappeared at the top of the Guadalupian and that this development is not a special, facially-controlled development of the Guadalupian type area, but recognizable worldwide.

This conodont event is still more important, because it coincides with another lineage, in which the serration disappeared. *Mesogondolella behnkeni* (Bando et al. 1980), still present in the Lamar, evolved into the unserrated *Clarkina rosenkrantzi* (Bender & Stoppel). Here, it also is not relevant for the stratigraphic evaluation that his development may be phylomorphogenetic change within a genus (*Mesogondolella*) or between two genera (*Mesogondolella* and *Clarkina*). *Clarkina rosenkrantzi* is the only gondolellid conodont of the Dzhulfian beds of Greenland and of the Zechstein Limestone in middle and NW Europe. This gondolellid fauna without serrated conodonts is very different from the Guadalupian conodont fauna with serrated conodonts (Kozur 1978; 1992b; 1992c; 1992d).

In the topmost Lamar a very distinct change in the radiolarian fauna can also be observed. *Follicucullus ventricosus* Ormiston & Babcock and *Ishigaconus scholasticus* (Ormiston & Babcock), the most common albailellids of the Late Permian Lopingian Series of the Circum-Pacific area and of the Tethys (toward the west until western Sicily) (Kozur 1993c), begin at this level.

Thus, two of the three important pelagic faunal elements show very distinct changes at the base of the *C. altudaensis* zone. The third important pelagic group, the ammonoids, are not yet well studied near the Guadalupian-Lopingian boundary. However, Furnish (1973) pointed out that the ammonoid fauna of the (upper) Lamar is post-Guadalupian. Also, the development of all other stratigraphically important fossil groups around the first appearance of *C. altudaensis* still needs to be studied. The lower Lamar yields *Yabeina* Deprat, a Tethyan Capitanian fusulinid genus. Above this level, *Paraboultonia* Skinner & Wilde, *Codonofusiella* Dunbar & Skinner and *Reichelina* Erk are common. Unfortunately, *Yabeina* is an immigrant and it is not clear if its uppermost occurrence in the lower Lamar corresponds to its uppermost

occurrence in the Tethys.

The uppermost part of the Kufeng (Gufeng, Kuhfeng) Formation, in which the unserrated *C. altudaensis* evolved from serrated *Mesogondolella*, corresponds to the Lengwu Member of the Tinjiashan Formation of Zhejiang Province, China (He 1980). At this stratigraphic level a very interesting brachiopod fauna occurs that contains, in addition to typical elements of the Guadalupian Maokou Formation such as *Unisteges maceus* (Ching) and *Orthotichia nana* (Grabau), typical and common elements of the Lopingian Longtan Formation, such as *Cathaysia chonetoides* (Chao), *Haydenella wenganensis* (Huang), *Leptodus nobilis* (Waagen), *Neochonetetes substrophomenoides* (Huang), *Tschernyschewia sinensis* Chao, and *Tyloplecta yangtzeensis* (Chao). Therefore, the brachiopod faunas also show distinct changes about at the same level where the serrated *Mesogondolella* disappeared and *C. altudaensis* appeared worldwide.

The second argument of Jin et al. (1993), that in the level of the transition from serrated *Mesogondolella* to the unserrated *Clarkina altudaensis* no geologic events occur, is rather a phenomenon local to South China. At the level where *Clarkina* of the *C. bitteri* / *C. leveni* group migrated into the depositional area of South China, the event favored by Jin et al. (1993) as the Guadalupian-Lopingian boundary, no pronounced geologic changes can be observed. Moreover, the level of immigration of a certain faunal group always has high potential to be a diachronous boundary, if this level is to be correlated with other occurrences of the immigrants outside South China. Therefore, this level is unsuitable for definition of the Guadalupian-Lopingian boundary. No changes of the radiolarian faunas occur at this level. It is not desirable to choose another level of immigration of Late Permian guideforms than it is to maintain the present base of the Dzhulfian stage at the base of the *C. leveni* zone, a level where many different Dzhulfian forms immigrated into the Transcaucasian Dzhulfian type area. This boundary can be defined within a cline from *C. liangshanensis* (Wang) to *C. leveni* and is therefore better suited as the level of immigration of *Clarkina* of the *C. bitteri* / *C. leveni* group into South China, species with an unknown immediate forerunner.

CONCLUSIONS

The easily recognizable *Clarkina crofti*, a deep pelagic member of the *Clarkina bitteri* / *C. leveni* lineage, has a high potential to become

a stratigraphically important form for deep pelagic conodont faunas, like *C. altudaensis* is for shallow pelagic ones. Further investigations in deep pelagic deposits of the Tethys, especially in the very fossil-rich deposits of western Sicily, are necessary to find this form in the Tethys.

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IMPACTS OF GEOPHYSICAL SEISMIC SURVEY VEHICLES ON PADRE ISLAND NATIONAL SEASHORE VEGETATION

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Abstract.—Vehicular impacts from geophysical seismic surveys on plant survival and regrowth were evaluated in five plant communities (low coastal sands, shoregrass flats, salty sands, marsh and lateral dunes) on Padre Island National Seashore during 1988 and 1989. Vegetative cover was initially reduced in all communities by multi-track vehicles. Vegetation recovery to original diversity was estimated at 18-24 months and recovery to original density was estimated to be in excess of 18-24 months. Plant communities most affected by seismographic truck damage were the least vegetated ones. The results of this study conclude that there was no permanent damage to the vegetation of any community impacted by multi-track vehicles.

Human activity can adversely affect vegetation and microclimate of barrier islands (McAtee & Drawe 1981; Judd et al. 1989; Lonard et al. 1991). Vegetation disturbance on these fragile areas can modify the environment such that plant reestablishment and subsequent stabilization of the area may be precluded (Odum 1959). The economic value of barrier islands as recreational areas and as physical protection for adjacent inland areas from storm surges may total millions of dollars annually (Weise & White 1980). The effects of vehicular traffic on the vegetation and microclimate of coastal ecosystems have been examined by several studies (Liddle & Greig-Smith 1975; Brodhead & Godfrey; 1977; Carls et al. 1990).

Padre Island National Seashore Park does not own mineral rights inside its boundaries. Mineral owners are allowed access to their leases through a process that mitigates and moderates impacts on resources. Trafalgar House Oil and Gas, Inc. completed a seismic survey of an area of the seashore north of Yarborough Pass and another area north of the Ranger Station during the summer of 1988. The objective of this study was to assess impacts of off-road vehicle use on native vegetation of the seashore.

STUDY AREA

Padre Island has a semi-arid littoral climate, influenced primarily by prevailing, moisture-laden winds. Average annual rainfall is about 710

mm with peaks occurring in spring and fall. Humidity is high throughout the year causing foggy conditions during winter and early spring. Southeasterly winds reaching velocities of 48 to 68 km/hr in spring carry salt spray inland. Temperatures are generally moderate, seldom becoming extreme (high or low). Killing frosts may not occur at all during some winters (Rechenthin & Passey 1967). Six months prior to and throughout the study rainfall was below average, totaling 410 mm in 1988 and 390 mm through the first 10 months of 1989 (National Seashore Records).

Soils of the island are characterized by deep sands mixed with shell fragments, and are seriously deficient in major plant nutrients (Drawe et al. 1981). General characteristics of the vegetation are those of a prairie, usually dominated by bluestems (*Andropogon* spp. & *Schizachyrium* spp.), sea oats (*Uniola paniculata*), and *Paspalum* spp. (cf. Rechenthin & Passey 1967). Major changes in the vegetation have occurred following the removal of cattle from the island in 1971.

METHODS AND MATERIALS

Two seismic lines crossed the seashore north of Yarborough Pass in the Little Shell Beach area. During the seismic survey, dynamite charges were set and exploded at 100 m intervals or 165 m where there were natural restrictions such as marshes or active dunes. Disturbances to vegetation were by crushing or uprooting by large multi-ton terra-tire vehicles (MTV's) with tracks approximately 100 cm wide and smaller all-terrain vehicles (ATV's) with tracks approximately 115 cm wide, using work corridors up to 23 m wide.

Plant species diversity and density were examined for five distinct plant communities first delineated by Rechenthin & Passey (1967): (a) low coastal sands (LCS), (b) shoregrass flats (SF), (c) salty sands (SS), (d) marsh (MA), and (e) lateral dunes (LD). Vegetation sampling was conducted during October 1988, April 1989, and September 1989. During initial sampling in October 1988, an unsuccessful attempt was made to distinguish ATV tracks from those of MTV's. The tracks were made during the summer of 1988, and by the time of initial sampling in October 1988, plant regrowth had masked over the ATV tracks. Therefore, no attempt was made to sample ATV tracks, and all efforts concentrated on sampling MTV tracks.

The sampling procedure consisted of locating a transect in a track-damaged area by pacing 30 steps down the track off an existing

permanent roadway, placing a surveyor's flag marker at the starting point, and sampling with a 10-point frame to record cover and frequency of plants encountered (Bonham 1989). The sampling frame was placed perpendicularly across the track-damaged area so that all 10 pin-drops were located within the track. One foliar hit and one basal hit were recorded for each pin drop. Standing dead material was recorded as a foliar hit and decumbent dead material was recorded as a basal hit. Frequency data were simultaneously recorded as follows: (a) all plant species hit by the pin of the point frame and (b) all additional plants found in the 5 cm belt between the two forward legs of the point frame. When all 10 sample-points had been recorded, the frame was moved 10 steps down the track to the next sampling station. Three hundred points were recorded in both the track-damaged area and in an adjacent no-track area. Point-frame locations for no-track samples were placed adjacent to each track-damage frame setting by taking 10 steps perpendicular from the last track-damage frame setting.

A measure of complexity of the various communities was relative frequency, because presence/absence data was recorded for all species on a 5 cm band across the 61 cm width of the point frame each time it was placed on the ground for cover measurements. Relative frequency was calculated for each species encountered during each sampling period.

Seventeen paired transects were sampled on three dates, October 1988, April 1989, and September 1989. The terra-tire track marks were still identifiable during April 1989, but many were covered by new vegetative growth by September 1989. After examination of the seismic lines on the ground, it was discovered that three communities (SF, SS, and MA) were poorly represented along the lines. Therefore, actual sampling resulted in locating eight pairs of transects in LCS, four pairs in LD, three pairs in MA, and one pair each in SF and SS.

Cover data were analyzed using repeated measures (MANOVA). There were no interactions ($P > 0.05$), thus the main effects could be tested. Means were separated using Fisher's protected Least Significant Difference procedure (Ott 1988). Comparison of sampling months was done with mean contrasts using the Super Anova statistical package (Abacus Concepts 1989). The Shannon Diversity Index was used to evaluate plant community diversity. A *t*-test was used to compared diversities between track-damaged and no-track areas (Magurran 1988).

Table 1. Plant species with highest relative frequency (%) of occurrence within five communities on Padre Island National Seashore.

Community	Track-Damaged	Forbs					Grasses and Grass-like				
		* <i>B.fru.</i>	<i>H.sub.</i>	<i>H.ann.</i>	<i>S.big.</i>	<i>S.emb.</i>	<i>M.lit.</i>	<i>P.mon.</i>	<i>S.sco.</i>	<i>S.pat.</i>	<i>S.vir.</i>
OCTOBER 1988											
Low coastal sands	Yes	-	-	1.6%	-	0.4%	-	14.1%	17.6%	5.7%	0.4%
	No	-	1.2%	2.9%	-	0.7%	-	16.4%	13.8%	4.2%	-
Lateral dunes	Yes	-	5.4%	9.6%	-	-	-	17.7%	2.4%	3.2%	-
	No	-	22.0%	1.3%	-	-	-	15.2%	2.1%	5.1%	-
Marsh	Yes	-	-	-	-	3.9%	-	21.1%	0.6%	19.4%	-
	No	2.9%	-	-	-	3.5%	-	12.4%	-	15.7%	0.3%
Shoregrass flats	Yes	2.3%	-	-	14.0%	-	53.5%	-	-	-	20.9%
	No	9.4%	-	1.9%	13.2%	-	43.4%	-	-	-	17.0%
Salty sands	Yes	-	-	6.7%	1.7%	25.0%	5.0%	-	-	-	-
	No	-	-	22.9%	3.6%	25.3%	4.8%	-	-	-	-
APRIL 1989											
Low coastal sands	Yes	-	1.1%	0.6%	-	0.1%	-	16.3%	16.3%	3.6%	1.1%
	No	-	1.5%	1.5%	-	1.0%	-	15.4%	13.6%	4.2%	-
Lateral dunes	Yes	-	20.7%	0.6%	-	-	-	16.2%	2.3%	4.7%	-
	No	-	20.2%	0.9%	-	-	-	20.0%	3.3%	7.6%	-
Marsh	Yes	1.9%	-	-	-	4.0%	-	18.1%	0.3%	21.8%	-
	No	1.9%	-	0.4%	-	4.7%	-	16.2%	0.3%	21.4%	-
Shoregrass flats	Yes	11.9%	-	3.4%	11.9%	-	45.8%	-	-	-	10.2%
	No	11.8%	-	9.8%	5.9%	-	52.9%	-	-	-	13.7%
Salty sands	Yes	1.2%	-	20.2%	2.4%	-	1.2%	-	-	-	-
	No	1.3%	-	24.4%	1.3%	-	-	-	-	-	-
SEPTEMBER 1989											
Low coastal sands	Yes	0.5%	1.0%	-	-	1.9%	-	18.5%	13.1%	2.8%	0.5%
	No	-	3.3%	0.5%	-	1.0%	-	18.8%	11.4%	3.9%	0.5%
Lateral dunes	Yes	-	13.4%	-	-	0.5%	-	16.7%	7.4%	4.5%	3.0%
	No	-	21.2%	-	-	-	-	15.9%	6.8%	4.6%	2.1%
Marsh	Yes	1.6%	0.5%	-	-	7.8%	-	18.2%	0.5%	17.4%	-
	No	-	0.5%	-	-	8.4%	-	20.2%	0.5%	20.0%	-
Shoregrass flats	Yes	11.8%	-	-	9.8%	-	52.9%	-	-	-	9.8%
	No	12.7%	-	5.5%	9.1%	-	50.9%	-	-	-	10.9%
Salty sands	Yes	-	-	16.3%	5.0%	-	1.3%	-	-	-	3.8%
	No	-	-	21.1%	4.4%	-	1.1%	-	-	-	1.1%

* *B.fru.* = *Borrichia frutescens*; *H. sub.* = *Heterotheca subaxillaris*; *H. ann.* = *Haplopappus annuus*; *S. big.* = *Salicornia bigelovii*; *S. emb.* = *Salomus embracteatus*; *M. lit.* = *Monanthochloe littoralis*; *P. mon.* = *Paspalum monostachyum*; *S. sco.* = *Schizachirium scoparium*; *S. pat.* = *Spartina patens*; *S. vir.* = *Sporobolus virginicus*

RESULTS

The flora of the seashore is complex. During this study, 33 species of grasses and grass-like plants and 63 species of forbs were encountered. Twenty-one forbs and 18 grasses and grass-like species had greater than 4% cover at one sampling period or another. Major species

Table 2. Species richness (total number of species encountered in sampling) in the communities of Padre Island throughout the study.

	October 1988	April 1989	September 1989
Low coastal sands			
Track-damaged	47	52	50
No-track	52	41	52
Lateral dunes			
Track-damaged	34	30	34
No-track	37	29	36
Marsh			
Track-damaged	28	30	31
No-track	29	27	28
Shoregrass flats			
Track-damaged	8	10	6
No-track	10	8	8
Salty sands			
Track-damaged	9	17	13
No-track	10	14	13

of forbs found were *Borrichia frutescens*, *Heterotheca subaxillaris*, *Haplopappus annuus*, *Salicornia bigelovii* and *Samolus embracteatus* (Table 1). However, grasses were represented in greater percentages, such as *Monanthochloe littoralis*, *Paspalum monostachyum*, *Schizachyrium scoparium* var. *littoralis*, *Spartina patens* and *Sporobolus virginicus*.

Green foliar cover differed ($P<0.05$) between track-damaged (23%) and no-track areas (29%). Comparing dates only and combining track and no-track data, there were no differences ($P>0.05$) in green foliar cover between October 1988 (26%) and April 1989 (24%) and between October 1988 and September 1989 (28%), but foliar cover was different between April 1989 and September 1989 ($P<0.05$). The greatest difference in foliar cover between track-damaged and no-track was recorded in October 1988 (Fig. 1a).

Among communities SF had the highest overall green foliar cover (41%) ($P<0.05$). The second highest green foliar cover was found in LCS (27%), and was different ($P<0.05$) from the other communities. The lowest green foliar cover was found in LD (22%). Salty sands and MA had similar cover (23 and 25%, respectively) ($P>0.05$). Green foliar cover was affected in a similar manner by MTV tracks (Fig. 2), except in SF, which may be a sampling artifact.

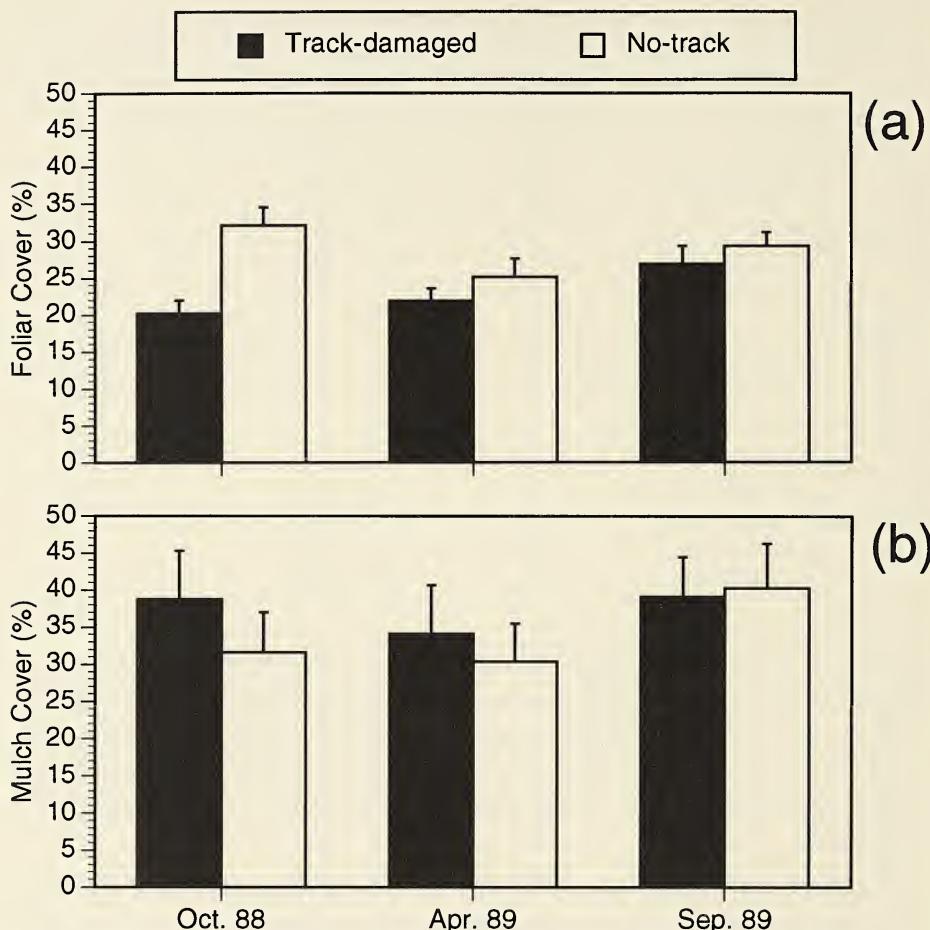


Figure 1. Overall mean (a) foliar cover ($C + SE$) and (b) mulch cover ($C + SE$) on track-damaged and no-track areas on Padre Island.

Standing dead plant material differed ($P < 0.05$) between track-damaged (2%) and no-track areas (14%). The cover of standing dead plant material was greater on no-track (10%) than on track-damaged areas (1%) in all communities throughout the study. There were no differences ($P > 0.05$) in cover of standing dead plant material between October 1988 (6%), April 1989 (9%), and September 1989 (8%). Tracks of MTV's destroyed all the standing dead material as recorded in October 1988 (Fig. 2).

Mulch cover (dead, decaying plant material) did not differ ($P > 0.05$) between track-damaged (37%) and no-track areas (34%). Mulch cover

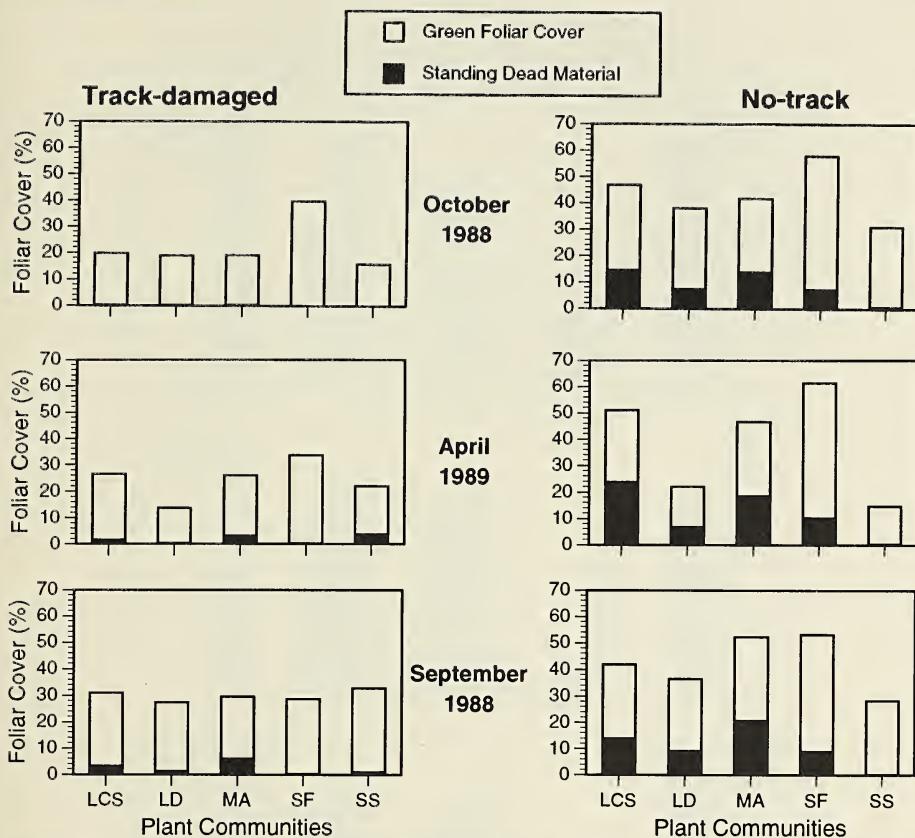


Figure 2. Foliar cover and standing dead material for the different communities on Padre Island. (LCS = low coastal sands; LD = lateral dunes; MA = marsh; SF = shoregrass flats; SS = salty sands).

between October 1988 (35%) and April 1989 (32%) was similar ($P > 0.05$), however, differences occurred ($P < 0.05$) between October 1988 and September 1989 (40%) and April 1989 and September 1989 (Fig. 1b). Over the length of the study, mulch cover follows a similar pattern when the individual communities are examined (Fig. 3).

The highest species diversity found was in LCS and in LD communities (Fig. 4), while the lowest diversity was found in the SF community. The diversity in LCS, LD and MA communities, when comparing track-damaged areas and no-track areas, was similar ($P > 0.05$) in every period sampled (Fig. 4). However, in the SF community, species diversity was lower during October 1988 and September 1989 and higher in April 1989 in the track-damaged than in no-track areas. Diversity in the SS community was lower ($P < 0.05$) in October 1988 and April 1989, and higher in September 1989 for track-damaged compared to no-track areas (Fig. 4).

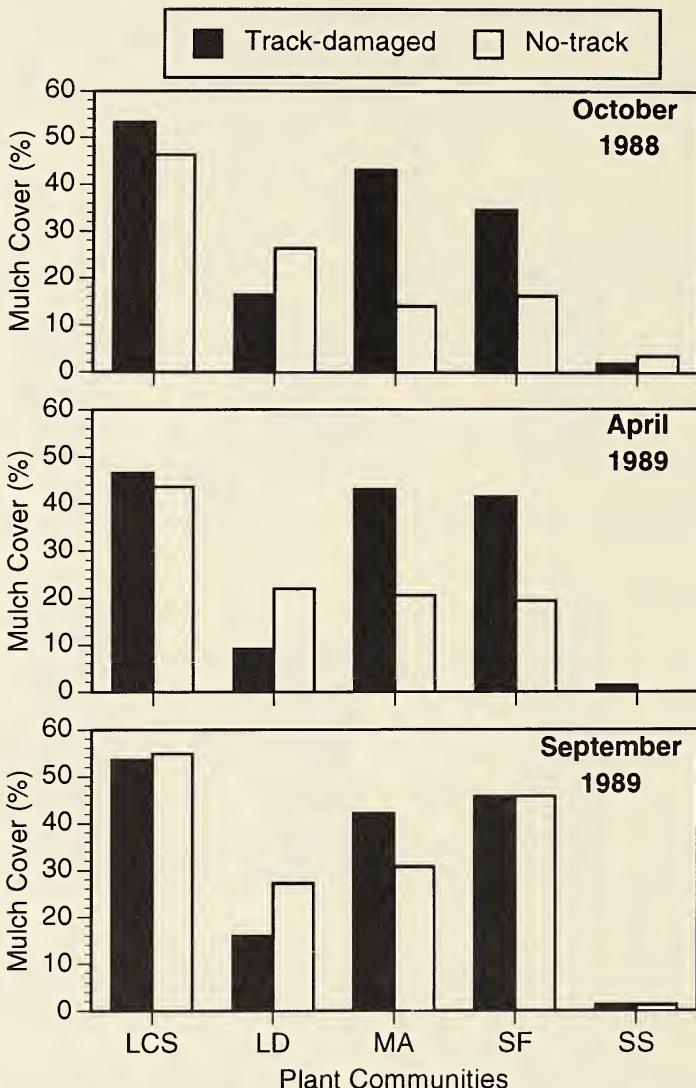


Figure 3. Mulch cover for the different communities on Padre Island comparing track-damaged and no-track. (LCS = low coastal sands; LD = lateral dunes; MA = marsh; SF = shoregrass flats; SS = salty sands).

Species richness was highest in the LCS and lowest in the SF and SS communities. Richness was not affected by the traffic of the geophysical survey vehicles working in the area (Table 2).

DISCUSSION AND CONCLUSIONS

The disparity in occurrence of the plant communities along track-damaged areas on the seashore was expected. Drawe et al. (1981) found

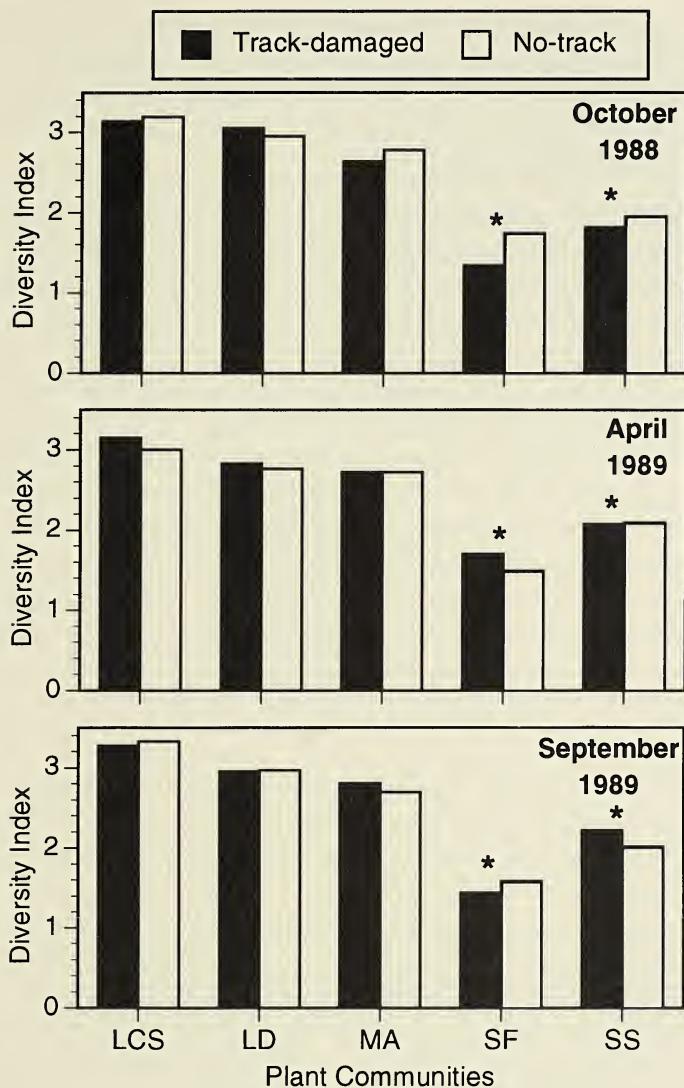


Figure 4. Shannon's diversity index for the different communities on Padre Island track-damaged and no-track areas. (LCS = low coastal sands; LD = lateral dunes; MA = marsh; SF = shoregrass flats; SS = salty sands; * = indicates similar diversity $P > 0.05$).

that four east-west transects located on the seashore between the two areas of seismic activity contained the following percentages of each community: gulf beach (5%); coastal dunes (18%); low coastal sands (61%); marsh (1%); shoregrass flats (13%); and salty sands (2%). Lateral dunes were not separated from beach dunes by Drawe et al. (1981).

Initially, plant cover was reduced by an average of 12% on MTV tracks. By the end of the study, the reduction of plant cover on the track-damaged areas was >5%. Therefore, vegetation recovery to original density would take in excess of 18-24 months, but the exact length of time was beyond this study.

At the April 1989 sampling there were more species and more green foliar cover in the track-damaged areas than in the no-track areas. More bare ground was found in the track-damaged areas, but revegetation was occurring. It may be that the track-damaged areas were placed back in an earlier stage of succession which contains a greater number of species. Undisturbed areas, especially in the low coastal sands and marsh communities, may be stagnated. The high cover of standing dead plant material could cause shading of the ground surface and inhibition of seedling establishment. Most nutrients found in standing dead material cannot be incorporated into the soil, except by some leaching. In an infertile soil such as the sands of Padre Island (Drawe et al. 1981), this can be a strong influence. Conversely, in track-damaged areas, standing dead material was crushed to the ground, reducing shading and placing the decaying plant material in direct contact with the soil where it could be broken down and the nutrients incorporated into the soil solution.

Seismographic activity initially set back plant succession in the track-damaged areas. This was evident in October 1988 when there were fewer species than expected and more bare ground in the track-damaged areas than in the no-track areas. It was also evident that these areas were rapidly recovering as shown by the amount of green foliar cover present by April and September 1989. More bare ground was found in the track-damaged area but revegetation was occurring. Drawe et al. (1981) found the vegetation of the seashore to be in an upward trend of succession following the removal of cattle in 1971. However, their work and that of McAtee & Drawe (1980; 1981) has shown the harsh nature of the environment of Padre Island, thus suggesting that the rate of plant succession would be slow following disturbance by seismographic vehicle traffic.

The vegetation of the seashore appeared to be in a mid-successional state. Drawe et al. (1981) found a large area immediately north of Little Shell Beach to be in lower successional stages, and predicted that following removal of cattle, vegetation of the seashore would slowly progress toward a mid- or even a tall-grass climax dominated by sea-coast bluestem, bushy bluestem (*Andropogon glomeratus*), and gulf

beach panicum (*Panicum amarum*). Areas impacted by recent seismic vehicle activity were dominated by low coastal sands communities in which seacoast bluestem was a dominant species and bushy bluestem was abundant.

The plant community with the most bare ground following seismographic vehicle activity was the salty sands, followed by lateral dunes. Conversely, the most vegetated communities were low coastal sands, marsh and shoregrass. Communities with original cover of both live and dead vegetation would be able to withstand the most disturbance. In this study, the greatest diversity occurred in the low coastal sands and the least in the shoregrass community. Therefore, based upon data and observations from the study, the community best able to withstand seismographic track damage would be the low coastal sands. The best example of how this actually worked in the field is to examine the seacoast bluestem prairie area (low coastal sands) that was used as an access road from the Yarborough Pass shell road to the southern end of the seismographic line. This area received some of the heaviest traffic of any area damaged by the trucks and the area was revegetating rapidly prior to the end of the study.

The communities most damaged by seismographic truck activity were salty sands and lateral dunes. These communities initially had the least diversity and the most bare ground. The track-damaged areas of the lateral dunes and salty sands were practically bare sand at the initial sampling in October 1988; however, by September 1989 these two communities were recovering.

Seashore personnel should continue to closely monitor all oil field activity to limit damage to native plant communities. Sensitive areas including marshes, foredunes, lateral dunes and salty sands communities should be particularly guarded. Offroad access across native plant communities should be primarily through well-vegetated low coastal sands or shoregrass communities in an advanced stage of succession. Marsh margins should be utilized sparingly. When bare sands appear or damage to vegetation is imminent is an offroad access track, the access should be moved to an undamaged area.

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KARYOTYPIC VARIATION IN SPOTTED SKUNKS
(CARNIVORA: MUSTELIDAE: *SPilogale*)
FROM TEXAS, MEXICO AND EL SALVADOR

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Abstract.—The karyotypes of two specimens of *Spilogale putorius interrupta* from Texas and Mexico and two specimens of *Spilogale putorius tropicalis* from El Salvador are examined. Karyotypic variation within the genus *Spilogale* is also reviewed.

The spotted skunks, genus *Spilogale*, comprise one of three genera in the subfamily Mephitinae. This genus was last reviewed by Van Gelder (1959) who recognized two species, *Spilogale pygmaea* and *S. putorius*. The pygmy spotted skunk is monotypic and restricted in distribution to the Pacific coastal plains of Mexico and Guatemala. Van Gelder (1959) considered *S. putorius* to be polytypic with 15 subspecies ranging from British Columbia southward through much of the United States, Mexico, and Central America. Jones et al. (1992) recognized the western form of *S. putorius* as a distinct species, *S. gracilis*. This study follows the nomenclature proposed by Jones et al. (1992), but recognizes that the specific and subspecific distributional boundaries of the *Spilogale putorius/S. gracilis* complex are in need of further clarification.

Four specimens of *Spilogale* were karyotyped during the course of this study. This report provides a description of karyotypes from these specimens, data on karyotypes of other specimens provided by Mead (pers. comm.) and a summary of karyotypic data from the literature. One of these karyotypes corrects an error in the literature, and two document previously undescribed variation. Collectively this information provides new insight relative to chromosomal evolution in this mustelid complex.

METHODS AND MATERIALS

Mitotic metaphase chromosomes were prepared from bone marrow following the techniques of Robbins & Baker (1983). Voucher specimens are deposited in the Museum of Texas Tech University (TTU) and the Carnegie Museum of Natural History (CM). Based on Hall

Table 1. Karyological variation within the genus *Spilogale* (AN = autosomal arm number; M = metacentric; SM = submetacentric; m = minute).

Taxon	2N	AN	Acrocentric pairs	Biarmed pairs	X	Y	Literature Reference
<i>S. pygmaea pygmaea</i>	48	86	3	20	M	m	Lee & Modi (1983)
<i>S. gracilis leucoparia</i>	58	70	21	7	M	m	Lee & Modi (1983)
<i>S. gracilis leucoparia</i>	60	—	—	—	—	—	Mead (pers. comm.)
<i>S. gracilis latifrons</i>	60	70	23	6	M	m	Hsu & Mead (1969)
<i>S. gracilis phenax</i>	60	—	—	—	—	—	Mead (pers. comm.)
<i>S. putorius ambarvalis</i>	64	70	27	4	M	m	Hsu & Mead (1969)
<i>S. putorius interrupta</i>	64	70	27	4	M	m	Hsu & Mead (1969)
<i>S. putorius interrupta</i>	62	70	25	5	SM	m	this study
<i>S. putorius interrupta</i>	64	70	27	4	M	m	this study
<i>S. putorius tropicalis</i>	58	68	22	6	SM	m	this study

(1981), this study examined two specimens each of *S. putorius interrupta* and *S. putorius tropicalis* collected from natural occurring populations in Texas, Mexico and El Salvador.

Material examined.—1 mi SE of Post, Garza County, Texas, one specimen of *Spilogale putorius interrupta* (TTU 17491). 2.5 mi SE of Altamira, Tamaulipas, México, one specimen of *Spilogale putorius interrupta* (TTU 14334). Los Marranitos, Departamento de La Paz, El Salvador, one specimen of *Spilogale putorius tropicalis* (CM 111000). Deininger Park near Amayo R., Departamento de La Libertad, El Salvador, one specimen of *Spilogale putorius tropicalis* (TTU 64152).

RESULTS AND DISCUSSION

The data reveal extensive karyological variation within the *S. putorius/S. gracilis* complex (Table 1). Within the complex, *S. putorius tropicalis* had a diploid number of 58 with 68 autosomal arms (Fig. 1), whereas *S. putorius interrupta* from Texas and Tamaulipas had diploid numbers of 64 and 62, respectively (not figured). This means that at least six different karyotypes are known for the complex. Perhaps there would be even more if complete data were available for *S. gracilis phenax* and the 2n=60 form of *S. gracilis leucoparia*. The diploid number of *S. gracilis phenax* was erroneously published by Hsu & Mead (1969) and subsequently cited by Lee & Modi (1983) as 64, rather than 60 (Table 1: Mead, pers. comm.).

Five of the karyotypes of the *S. putorius/S. gracilis* complex (Table 1) appear to be interconvertable by centric fusions/fissions (= Robert-

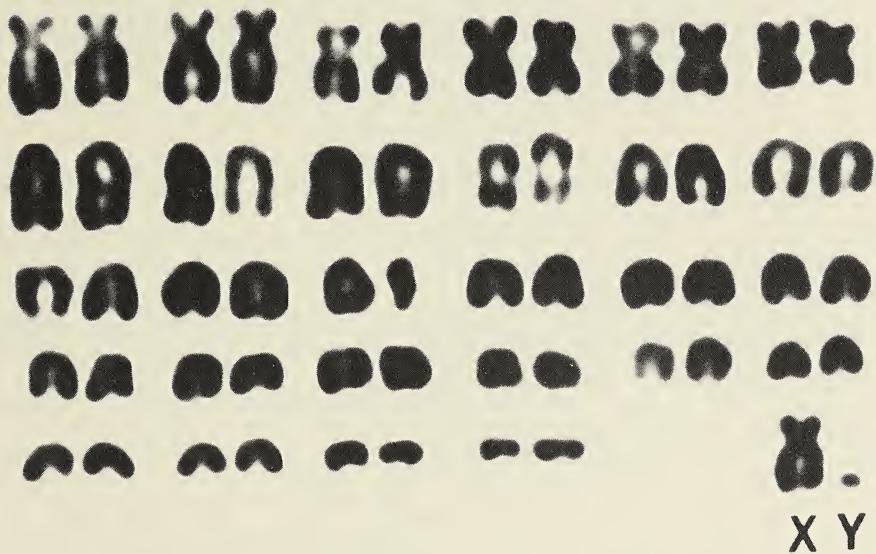


Figure 1. Nondifferentially stained karyotype of a male *Spilogale putorius tropicalis* (CM 111000) from Los Marranitos, Departamento de La Paz, El Salvador.

sonian events). The number of arms in the autosomal complement of the specimens from El Salvador is lower than the value characteristic of northern spotted skunks, thus cannot be described solely as Robertsonian variation. It is noteworthy that specimens with diploid numbers of both 58 and 60 have been found in *S. gracilis leucoparia*. As currently recognized, this subspecies appears to be a composite of two diploid numbers.

Geographic distribution of karyotypic variation observed in *Spilogale* does not fit the pattern expected of a Rassenkreis (Mayr 1970:423). Furthermore, strong differences in reproductive characteristics have been shown for karyotypes with only Robertsonian differences. Also, variation in the number of arms of the autosomes, such as observed in the material from El Salvador, often signals specific differences. Based on karyotypic and reproductive data (Mead 1967; 1968a; 1968b), it is worth examining geographical distributions and boundaries of chromosomal races to determine if the different cytotypes are behaving like biological species. Definitive answers must await further comparative studies, especially in zones of presumptive intergradation.

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PECTOLYTIC ENZYMES PRODUCED
BY THE PHYTOPATHOGENIC FUNGUS
COLLETOTRICHUM GLOEOSPORIOIDES

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Abstract.—The effect of different carbon sources on the production of extracellular pectolytic enzymes of *Colletotrichum gloeosporioides* was investigated. Production of polygalacturonase and pectinesterase was induced by pectin, sodium carboxymethyl cellulose, and xylan. Production of these enzymes was repressed or completely inhibited in the control cultures containing glucose as a carbon source and enzyme inducer. Maximum production of polygalacturonase and pectinesterase was induced when sodium carboxymethyl cellulose was used as the carbon source. The results indicate that the pectolytic enzymes of *C. gloeosporioides* may be produced in sequence, i.e., the production of polygalacturonase is followed by the secretion of pectinesterase.

Direct penetration of susceptible hosts by the infective hyphae of phytopathogenic fungi is facilitated by the production of cutinases (Agrios 1988). Penetration of the host is followed by disintegration of the pectic substances of the middle lamella and the primary cell wall by pectolytic enzymes (Kenaga 1974; Agrios 1988). The production of pectolytic enzymes has been induced in cultures of plant pathogenic fungi when these organisms were grown on media containing various carbon sources and enzyme inducers. These carbon sources include sugar polymers (Cooper & Wood 1973), sodium polypectate and pectin (Pegg 1981; Alana et al. 1989) and sugar beet cell walls (Bugbee 1990).

Colletotrichum gloeosporioides (Penz.) Sacc., anamorph of *Glomerella cingulata* (Ston.) Spauld. & Schrenk., has a wide host range including many plants of economic importance. *Colletotrichum gloeosporioides* causes leaf spots on ornamental plants such as calendula, hibiscus, jasmine and passiflora (Pirone 1978); it attacks tropical plants causing cacao anthracnose, coffee dieback and yams anthracnose (Cook 1978); it causes anthracnose diseases and fruit rot in strawberries and apples (Maas & Howard 1985). The primary objectives of this work were to identify the pectin degrading enzymes of *C. gloeosporioides* and to determine the effects of the carbon source on the production of these enzymes by *C. gloeosporioides*.

METHODS AND MATERIALS

Organism and culture conditions.—Stock cultures of *Colletotrichum gloeosporioides* were maintained on PDA slants (Difco, B13). The fungus was previously grown in 250 ml flasks with 125 ml of a medium containing: 0.2 g/l $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.1 g/l $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, 20.0 g/l glucose in Na-citrate buffer at pH 4.8. After four days growth at 26° C, 5.0 ml of mycelium inoculum was washed twice in distilled water and transferred to the growing medium. The medium for the production of pectinases contained: 1.5 g/l NH_4NO_3 , 2.4 g/l K_2PO_4 , 0.8 g/l MgSO_4 , 0.8 g/l $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, 0.72 mg/l $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$, 0.44 mg/l $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 2.0 mg/l $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$, 0.40 mg/l ZnCl_2 , and 10 g/l carbohydrate. The carbohydrates used as carbon sources and enzyme inducers included: sodium polypectate, apple pectin, xylan (Sigma Chemical Company), and sodium carboxymethyl cellulose (CMC, Aqualon Company, type 7HF). The control cultures had glucose as the sole carbon source. The pH of the growing medium was adjusted to 5.0 with 0.1 N KOH. Incubation of the cultures was carried out for seven days in covered 250 ml flasks on an orbital shaker at 80 rpm at 26°C.

Enzyme preparation and assays.—Culture fluids were collected after seven days of growth in the liquid medium. The culture fluids were centrifuged (3,852 xg, 30 minutes, 10°C) to obtain a clear supernatant. The supernatant was subsequently used for the determination of extracellular enzyme activity. For simplification, the collected supernatant is hereafter referred to as the enzyme. All tests were replicated four times.

Polygalacturonase (Pectinase, EC 3.2.1.15).— Polygalacturonase activity was measured by combining 1.0 ml of enzyme with 5.0 mg of sodium polypectate in 1.0 ml of 0.05 M sodium citrate buffer (pH 5.0) and incubating the reaction mixture for 120 minutes at 40°C. The tubes were stirred once during incubation. After centrifugation, the concentration of galacturonic acid or its reducing sugar equivalent in the supernatant was determined using the dinitrosalicylic reagent (Miller 1959).

Pectinesterase (Pectin methylesterase, EC 3.1.1.11).— Pectinesterase activity was measured by combining 1.0 ml of enzyme with 5.0 mg of pectin in 1.0 ml of 0.05 M sodium citrate buffer, (pH 4.8). The reaction mixture was incubated at 40°C for 120 minutes. After centrifugation, the concentration of galacturonic acid or its reducing sugar equivalent in the reaction mixture was measured using the dinitrosalicylic reagent (Miller 1959).

Table 1. Specific activities¹ of two pectinases produced by *Colletotrichum gloeosporioides* grown in media containing different carbon sources.

Carbon source	Enzymes		
	Polygalacturonase	Pectinesterase	Total protein ²
Sodium polypectate	0.0	1.86 ± 0.21	3.08 ± 0.15
Pectin	62.43 ± 4.19	15.41 ± 1.44	2.45 ± 0.17
CMC	91.95 ± 2.31*	24.03 ± 5.39	0.41 ± 0.03
Xylan	30.14 ± 0.53	19.68 ± 1.61	1.86 ± 0.16
Glucose	0.0	0.0	0.0

¹ Usp/min/mg of protein. Mean ± SD of four replications.

² mg/ml.

* Using one-way ANOVA and Duncan's MRT, significantly different from other values in the same group.

Protein determination.—Extracellular total protein in the crude supernatant was determined with the BCA reagent (Pierce Chemical Company) using bovine serum albumin as a standard.

Data analysis.—The results were expressed as units of specific enzyme activity (Usp) and represent means plus or minus the standard deviation of four replications. Each unit of enzyme specific activity was calculated as the amount of enzyme that liberated one micromole (μM) of galacturonic acid (or its reducing sugar equivalent) per minute per mg of protein under the assay's conditions. Statistical analyses of experimental data were made with one-way analysis of variance (ANOVA) and Duncan's multiple range test (MRT).

RESULTS

Polygalacturonase.—Production of polygalacturonase was induced in cultures containing pectin, CMC and xylan as carbon sources and enzyme inducers. No polygalacturonase activity was detected in the fluids obtained from cultures containing sodium polypectate or glucose as carbon sources (Table 1). Maximum polygalacturonase activity (91.95 Usp) was measured in fluids collected from cultures containing CMC (Table 1). This activity was significantly higher ($P = 0.05$) than the activities assessed in fluids obtained from cultures with pectin or xylan (62.43 and 30.14 Usp, respectively).

Polygalacturonase activities measured in fluids from cultures with pectin or xylan as carbon sources were 67.9 and 32.7%, respectively of

the activity measured in fluids from cultures with CMC (Table 1). The activities of this enzyme measured in the fluids from cultures containing pectin (62.43 Usp) were significantly higher ($P = 0.05$) than the activities measured in fluids from cultures containing xylan (30.14 Usp, Table 1).

Pectinesterase.—Production of pectinesterase was induced in cultures containing sodium polypectate, pectin, CMC and xylan as carbon sources. Maximum pectinesterase specific activity (24.03 Usp) was measured in fluids harvested from cultures with CMC (Table 1). This activity was significantly higher ($P = 0.05$) than the activities assessed in fluids obtained from cultures with sodium polypectate or pectin (1.86 and 15.41 Usp, respectively).

The pectinesterase activity measured in fluids obtained from cultures containing CMC was higher than the activity measured in fluids collected from cultures with xylan (19.68 Usp) as carbon source. However, the difference between these activities (4.35 Usp) was not statistically significant.

Pectinesterase activities measured in the fluids from cultures containing xylan (19.68 Usp) were significantly higher ($P = 0.05$) than the activities measured in fluids from cultures containing sodium polypectate (1.86 Usp). The activities of this enzyme measured in fluids from cultures containing xylan were slightly higher than the activities of this enzyme assessed in fluids from cultures with pectin (15.41 Usp) as the carbon source. The difference (4.27 Usp) between these activities was not statistically significant. No pectinesterase activity was detected in fluids of the control cultures containing glucose as carbon source.

DISCUSSION

Although the highest amount of extracellular protein determined in this study was found in fluids collected from cultures with sodium polypectate as the carbon source, it appears that only a small part of it was pectinesterase.

Whereas the production of polygalacturonase was induced in cultures of *C. gloeosporioides* containing pectin, CMC and xylan as carbon source, CMC was the most effective inducer of this enzyme. Sodium polypectate did not induce the secretion of polygalacturonase by *C. gloeosporioides* under the conditions of this study. It has been reported that plant pathogenic fungi can be induced to secrete polygalacturonase

and pectinesterase when grown in liquid media with the appropriate carbon source (Cleveland & McCormick 1987; Cooper & Wood 1973; Crawford & Kolattukudy 1987; De Lorenzo et al. 1987).

Pectinesterase activities were measured in fluids collected from cultures with sodium polypectate, pectin, CMC and xylan. Production of both enzymes by *C. gloeosporioides* was repressed or completely inhibited when the growing medium contained glucose as the sole carbon source. Repression of the induction of polygalacturonase and other pectic enzymes by glucose or galacturonic acid used as carbon sources has been reported in other studies of phytopathogenic fungi (De Lorenzo et al. 1987; Leone & Van Den Heuvel 1987).

The polygalacturonase accumulated in fluids obtained from cultures containing CMC was nearly four times higher than the amount of pectinesterase determined in the same fluids. It is probable that the concentration of these enzymes in relation to each other is an indication of the sequence in which the enzymes were produced, i.e., the fungus produces polygalacturonase first and then, pectinesterase. The production in sequence of pectic enzymes has been demonstrated in similar studies of plant pathogenic fungi (Bahkali 1987; Leone & Van Den Heuvel 1987). In these studies, polygalacturonase was detected first in the culture filtrates and was followed by pectinesterase.

SUMMARY

Secretion of polygalacturonase and pectin esterase was induced in liquid cultures of *C. gloeosporioides* when pectin, CMC or xylan are used as sole sources of carbon and enzyme inducers. Whereas CMC and pectin were the most effective inducers of polygalacturonase, CMC and xylan induced the highest production of pectinesterase.

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**WINTER PHENOLOGY AND FRUGIVORY
OF AMERICAN ROBINS AND CEDAR WAXWINGS
ON THE EDWARDS PLATEAU OF CENTRAL TEXAS**

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Abstract.—Timing of arrival, numbers, and fruit eating habits of wintering American Robins (*Turdus migratorius*) and Cedar Waxwings (*Bombycilla cedrorum*) were studied during two consecutive years (1989-90, 1990-91) in the Edwards Plateau region of central Texas. During the first year, robins were common during the fall migration season then declined and did not become abundant until middle of November. Waxwings were absent or rare until December. Both species were rare during the second year. Waxwings consumed four different species of fruit present in the area while robins consumed only two species of fruit in addition to insects. The most important food item for both species during the winter months was Ashe juniper whose production of fruit appears to determine the presence and abundance of both species in the Edwards Plateau region.

The American Robin (*Turdus migratorius*) and Cedar Waxwing (*Bombycilla cedrorum*) are two North American migrant species with large wintering ranges within the United States (Root 1988). High densities of these species are present during the winter months in southern states; particularly Oklahoma, Texas, Louisiana, and Georgia (Root 1988). Wintering ranges do, however, extend well into Mexico (robin) and farther south to Central America and the Caribbean (waxwing).

Both American Robins and Cedar Waxwings have been well studied in their breeding range and during their reproductive period (see Hamilton 1943; Knupp et al. 1977; Howell 1942; Young 1955; James & Shugart 1974; Weatherhead et al. 1991 for robins, and Putnam 1949; Sutton 1967 for waxwings). Less information exists regarding their winter population distributions, abundances, movements and feeding ecology. General information regarding these species winter range (Root 1988) and other aspects of winter ecology such as flock movements and diets is available (McPherson 1987). In Texas, specific information regarding these species within a geographical area is usually limited to occurrence data (Oberholser 1974; Pulich 1979 for Tarrant County; Wauer 1985 for Big Bend National Park; Rappole & Blacklock

1985 for Coastal Bend). This study reports on population movements and fruit feeding behavior of American Robins and Cedar Waxwings wintering in the Edwards Plateau region of central Texas. The objectives were to study time of arrival and bird movements to the area during fall and winter, relative population abundance and frugivory of robins and waxwings wintering in the Edwards Plateau region.

STUDY AREA

This study was conducted at the Texas Agricultural Experiment Station at Sonora, Texas. The 1430 ha station is located 45 km southeast of Sonora at approximately 100° west longitude and 30° north latitude. Vegetation in the area is shortgrass grassland with scattered Oak-Juniper mottes. Main oak species are live oak (*Quercus virginiana*) and shin oak (*Q. pungens*) with Ashe juniper (*Juniperus ashei*) the dominant woody plant species present throughout the area. Ashe juniper is found in densities of 640 trees per ha (Smeins unpubl. data) and has a canopy cover that varies from 30 to 40% throughout the station and can be as high as 70% in other areas of the Edwards Plateau (Van Auken 1988).

METHODS AND MATERIALS

Two census transects (2 km in length), established along the center of pastures, were conducted to observe feeding and determine relative abundance of wintering birds in the area. Ten points were located every 200 m to conduct unlimited area point counts. Upon arrival at each point two minutes were waited before beginning an eight minute count during which all birds observed were recorded. While both transects were used to observe feeding activity, only one was used as to evaluate relative abundance of birds. The two walk-through transects were conducted once per week from 4 September 1989 through 25 March 1990. Transects were also conducted once monthly from August 1990 to February 1991, except for January when two transects were conducted. Census transects were began at 0800 hr and continued to approximately 1000 hr. Bird feeding activity (fruits consumed) was determined by making trips, in addition to transects, throughout the area to attempt and locate feeding birds during all periods of the day throughout the winter months. All foraging attempts observed were recorded as to whether fruit or other food type was taken. When the entire flock was visible an attempt was made to count (if relatively small) or estimate the number of individuals. To determine period of

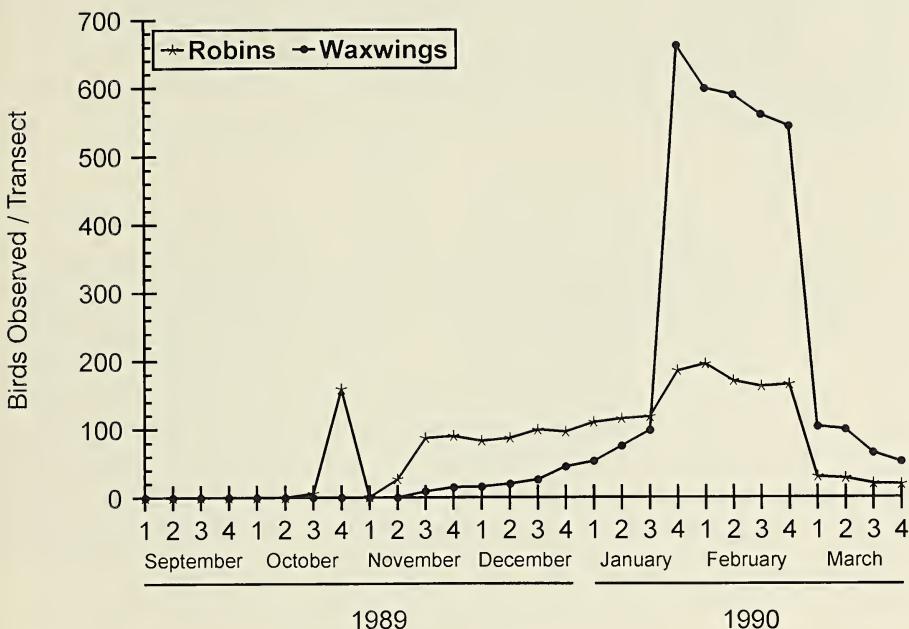


Figure 1. Cedar Waxwing and American Robin phenology and abundance (number of birds observed during transects) at the Texas Agricultural Experiment Station at Sonora during fall and winter 1989-1990.

fruit availability all fruiting species, and individual plants, encountered along the transects were identified and monitored regularly for fruit ripening. Fruit ripening was determined through visual inspection.

RESULTS

Bird phenology and abundance.—During the 1989-1990 winter, robins and waxwings were present in large numbers. Robins were first observed on 23 October while waxwings were first seen 18 November. No robins or waxwings were observed during the 8 transects conducted, or at any other time while in the field, during the fall and winter of 1990-1991. Two robins and 10 waxwings, however, were observed by station staff (B. Magaña, pers. comm.) on 20 November and 10 December, respectively.

Changes in number of robins and waxwings observed along transects conducted in 1989-1990 followed similar patterns of relative abundance (Fig. 1). Significant increases in numbers of birds were observed in late fall (robins) and dramatic increases of waxwings in early winter. Robin

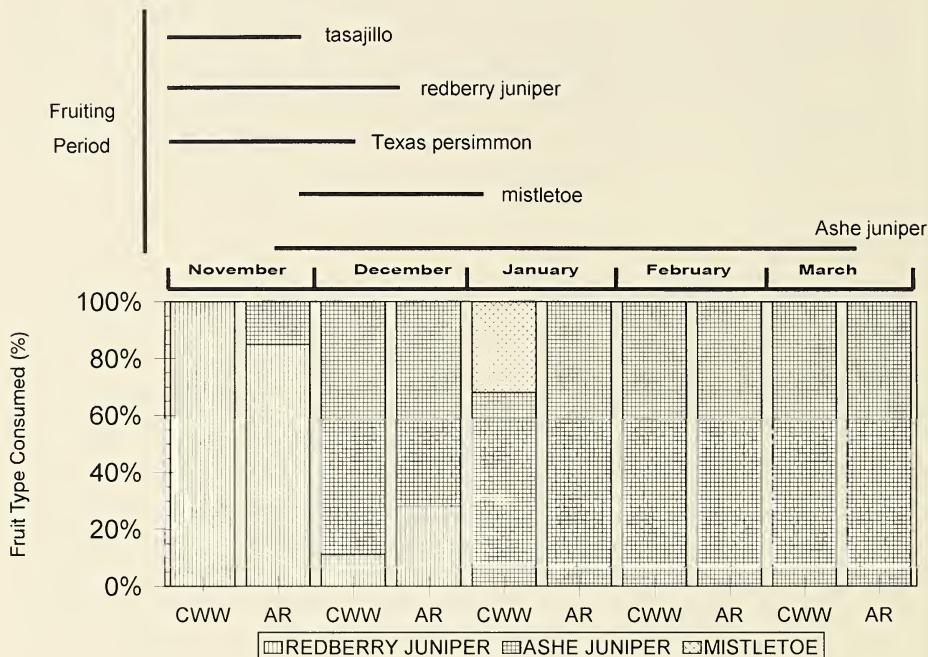


Figure 2. Fruit type consumed by American Robins and Cedar Waxwings during November and December 1989 and January - March 1990 at the Texas Agricultural Experiment Station at Sonora. (CWW = cedar waxwing, AR = American robin). The period of fruit ripening of the different fruit producing plants on the study area are represented above graph.

numbers increased during the latter part of October but declined during the first two weeks of November only to increase again in the latter part of that month. Robin numbers remained relatively constant (at approximately 100) between November through mid-January 1990 then peaked and remained high through February. Waxwings were present in low numbers beginning in late November and peaked in January remaining high through February and decreasing drastically in early March.

Avian frugivory and fruit availability.—During the fall months three fruiting species were observed throughout the area, tasajillo (*Opuntia leptocaulis* DC.), red-berry juniper (*Juniperus pinchotii* Sudw.) and Texas persimmon (*Diospyros texana* Scheele.) (Fig 2). During the winter three different species were observed fruiting: mistletoe (*Phoradendron spp.*), honeysuckle (*Lonicera albiflora* T. & G.), and Ashe juniper (Fig. 2). Only two honeysuckle plants were encountered

but no birds were observed feeding on these fruits. Mistletoe was more abundant but had localized distributions being associated mainly with mesquite (*Prosopis glandulosa* Torr.) plants found in the area, mostly away from transects. Ashe juniper was the most common plant in the area both in numbers and in quantity of fruit produced during the winter months (Chavez-Ramirez 1992).

Cedar Waxwings were strictly frugivorous during the winter with 100% (foraging attempts = 1097) of foraging observations recorded as taking fruit. By contrast robins foraged on both fruit and invertebrates, primarily grasshoppers. Foraging observations (foraging attempts = 469) of American Robins resulted in winter diets consisting of 65% fruit and 35% invertebrates.

Both species foraged in flocks and on many occasions were observed feeding on the same tree at the same time. Flock size averaged 56.8 birds and ranged from 3 to 800 ($SD = 126.5$, $N = 44$) for waxwings and averaged 10.4 birds and ranged between 2 and 50 ($SD = 10.5$, $N = 79$) for robins. Waxwings were highly social forming tightly structured flocks while robins formed loose flocks. A tightly structured flock is one where the birds fly or perch close together and from a distance seems like a unit, while a loose flock resembles more a group of individual birds flying in the same direction, not a single unit.

American Robins and Cedar Waxwings wintering in the area during 1989-1990 were observed to consume 2 and 4 species of fruit, respectively (Fig 2). The fruit used by waxwings was Ashe and red-berry junipers, mistletoe, and tasajillo, while robins were observed to consume fruit only from the two juniper species. During November waxwings were observed ($N = 131$) to consume only red-berry juniper, while American Robins were observed ($N = 62$) to consume mostly red-berry but also some Ashe juniper fruit. Use of Ashe juniper fruit increased once fruit ripening began in December. Ashe juniper made up more than 90% of observations of fruit foraging by waxwings ($N = 499$) and more than 70% of observations of fruit foraging by robins ($N = 119$) during December. During January ($N = 80$), February ($N = 23$), and March ($N = 17$) for robins and February ($N = 280$) and March ($N = 77$) for waxwings 100% of observations on fruit feeding were on Ashe juniper. Detailed aspects of foraging behavior while feeding on Ashe juniper fruit is presented in Chavez-Ramirez & Slack (1994).

DISCUSSION

Cedar Waxwings and American Robins showed highly frugivorous habits during the winter months on the Edwards Plateau. Waxwings are well known for being primarily frugivorous (Stiles 1984), while robin diets have been found to consist of high quantities of fruit during the fall and winter months (Wheelwright 1986). Differences in monthly fruit use between fall and winter by American Robins and Cedar Waxwings was a direct response to availability of seasonally ripe fruit. Red-berry juniper, the primary food item of waxwings and robins in November, is a fall fruit-ripening species that had little ripe fruit left by December. Fruit of Ashe juniper, a winter ripening species, was the primary food item of both species in December and the remaining winter months. Waxwings foraged on mistletoe fruit during January which is considered a preferred food item of this species in Oklahoma (Sutton 1967; McPherson 1987). In this study, however, waxwings appeared to feed on the most abundant fruit available within the area. Ashe juniper could be considered the only winter fruit available in the study area since mistletoe and honeysuckle are present in extremely low numbers. It is not surprising that Ashe juniper is the primary food item taken by wintering robins and waxwings in this area since Ashe juniper fruit is found in large quantities throughout the winter months in some years.

During the 1989-1990 winter the increase in robin and waxwing densities corresponded with the beginning of Ashe juniper fruit ripening in early December. Great influx of waxwings has been reported during the end of December in Tarrant county, Texas (Pulich 1979) and during February in Oklahoma (McPherson 1987). The dramatic increase in numbers of both species observed through late November and December suggests the wintering populations of these species are responding to the availability of Ashe juniper fruit in the Edwards Plateau. The typical winter wanderings of waxwing flocks previously reported in other areas may indicate birds from a large portion of the state are responding to fruit availability in this area. Before Ashe juniper fruit ripening began, the low numbers of waxwings and robins observed was likely due to the low availability of fruit present during that time. The sudden increase in number of robins observed in October was likely the result of influx of migratory individuals through this area.

The presence of juniper is believed to be the primary factor defining areas of high winter densities of Cedar Waxwings (Root 1988), however the factor determining the presence and high densities of both waxwings and robins in the Edwards Plateau is production of fruit by Ashe

juniper. Waxwings and robins were completely absent from this area of high juniper abundance in the winter of 1990-1991 which was a year of low fruit production by Ashe juniper.

Fruit production and presence of wintering waxwings and robins has been monitored during five consecutive winter seasons since 1987. Evidence thus far suggests Ashe juniper produces large fruit crops only every other year in the Edwards Plateau (Chavez-Ramirez 1992). During all monitored winters the presence of waxwings and robins in the study area has corresponded with that of fruit production by Ashe juniper (Chavez-Ramirez 1992).

Large wintering populations of waxwings and robins appear to respond to fruit availability in the Edwards Plateau. Where they spend the winter in years of fruit scarcity in this area is not known. It is possible that waxwings and robins migrate longer distances in years of low fruit production in the Edwards Plateau and spend the winter in Mexico. They may also spend the winter in other areas in southern portions of the United States where they are known to winter. Large numbers of American Robins are known to winter and feed on yaupon (*Ilex vomitoria*) during the winter in areas of eastern and coastal Texas (pers. observ.). Because of the large numbers of wintering waxwings and robins in the Edwards Plateau in years of fruit production by Ashe juniper a decrease in the number of wintering birds must be observed in other areas. Conversely, in years of low fruit production in this area an increase in numbers of birds of these two species should be observed in other areas of their winter range.

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NEW COUNTY RECORDS FOR TEN SPECIES OF BATS
(VESPERTILIONIDAE AND MOLOSSIDAE)
FROM TEXAS

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Abstract.—Bats submitted to the Texas Department of Health for rabies testing were identified, preserved and deposited with the holdings of the Museum at Texas Tech University. These specimens represent 51 new county records for 10 different species of bats in Texas. Records were documented for nine vespertilionids of six genera (*Myotis*, *Lasionycteris*, *Pipistrellus*, *Eptesicus*, *Lasiurus*, *Nycticeius*), and one molossid (*Tadarida*).

Since August, 1994, the authors have been assisting the Zoonosis Control Division of the Texas Department of Health by identifying bats submitted to the agency for rabies testing. Following testing, approximately 700 specimens collected throughout the state of Texas were shipped to the Museum on ice or preserved in 10% formalin. Accompanying each specimen was a corresponding data form, which included the date, county, and sometimes city of collection. Bats were identified, preserved in alcohol, and deposited in the Natural Science Research Laboratory of the Museum of Texas Tech University (TTU). Based on distribution maps provided in Schmidly (1991) and Davis & Schmidly (1994), 51 new county records for 10 species of bats were determined and are presented in the following species accounts.

Myotis velifer incautus (J. A. Allen)
Cave Myotis

In Texas, the cave myotis is a common resident of the western two-thirds of the state, with *M. velifer incautus* occurring in the south and *M. velifer magnamolaris* being restricted to the north (Schmidly 1991). However, records from East Texas are lacking (Schmidly 1991; Davis & Schmidly 1994). This report documents specimens from Caldwell, Milam, and Nueces counties. These bats, each of which is referred to *M. velifer incautus*, help define the eastern limits of the cave myotis in Texas.

Material examined.—Caldwell County (locality unspecified), Texas, 1 September 1993, one female specimen (TTU 68617). Milam County (locality unspecified), Texas, 6 October 1993, one male specimen (TTU 68618). Nueces County (locality unspecified), Texas, 17 September 1993, one female specimen (TTU 68619).

Lasionycteris noctivagans Le Conte
Silver-haired Bat

Silver-haired bats range throughout much of Texas as a fall-spring migrant (Schmidly 1991), but actual records are spotty. A single specimen was acquired from Ector County in West Texas. This record aids in filling in a large distributional gap for this species in West Texas.

Material examined.—Ector County (locality unspecified), Texas, 16 October 1993, one male specimen (TTU 68620).

Pipistrellus subflavus subflavus (F. Cuvier)
Eastern Pipistrelle

With the exception of a few aberrant records (Dowler et al. 1992; Jones, et al. 1993; Yancey et al. 1995), the eastern pipistrelle in Texas primarily is restricted to the eastern two-thirds of the state and the eastern Panhandle. This report documents new records from Bastrop, Fayette, Guadalupe, and Hays counties in east-central Texas; Tarrant and Wood counties in northeastern Texas; and Gray County in the north-eastern Panhandle. The records from east-central and northeastern Texas fill in gaps well within the known range of this species. The specimen from Gray County in the Panhandle represents the northernmost record of occurrence for this species in Texas.

Material examined.—Bastrop County (locality unspecified), Texas, 25 March 1994, one male specimen (TTU 68654). Fayette County (locality unspecified), Texas, 19 August 1994, one female specimen (TTU 68655). Gray County (locality unspecified), Texas, 30 August 1994, one female specimen (TTU 68656). Guadalupe County (locality unspecified), Texas, 14 October 1993, one female specimen (TTU 68657). Hays County (locality unspecified), Texas, 17 September 1993, one female specimen (TTU 68658). Tarrant County (locality unspecified), Texas, 7 September 1994, one female specimen (TTU 68659). Wood County (locality unspecified), Texas, 16 October 1994, one female specimen (TTU 68660).

Eptesicus fuscus fuscus (Palisot de Beauvois)
Big Brown Bat

In Texas, the big brown bat has a disjunct distribution, with the subspecies *E. fuscus pallidus* occurring in the northwestern and Trans-Pecos areas, and *E. fuscus fuscus* occupying East Texas (Schmidly 1991). During this study a single specimen each from both Angelina

and Liberty counties in East Texas were examined. These new records fill in distributional gaps in the known range of *E. fuscus fuscus*.

Material examined.—Angelina County (locality unspecified), Texas, no specific date 1995, one male specimen (TTU 68621). Hardin, Liberty County, Texas, 2 March 1995, one male specimen (TTU 68622).

Lasiurus borealis (Müller)
Eastern Red Bat

The eastern red bat ranges across Texas, but is particularly common in the eastern part of the state (Schmidly 1991). However, there are many counties in Texas for which there are no known specimens of *L. borealis*. This report documents the occurrence of this species from 17 of these counties, all of which are in central or eastern Texas. They are: Austin, Brown, Burleson, Cooke, Gonzales, Hays, Kleberg, Llano, Matagorda, Nolan, Orange, Robertson, Somervell, Tom Green, Waller, Wise, and Wood counties.

Material examined.—Austin County (locality unspecified), Texas, 19 July 1994, one female specimen (TTU 68623). Brown County (locality unspecified), Texas, 8 July 1993, one specimen of undetermined sex (TTU 68624). Burleson County (locality unspecified), Texas, 8 September 1994, one female specimen (TTU 68625) and one specimen of undetermined sex (TTU 68626). Cooke County (locality unspecified), Texas, 13 October 1993, one male specimen (TTU 68627). Gonzales County (locality unspecified), Texas, 23 June 1994, one female specimen (TTU 68628). Hays County (locality unspecified), Texas, 14 September 1993, one female specimen (TTU 68645); Hays County (locality unspecified), Texas, 26 May 1994, one female specimen (TTU 68629). Kleberg County (locality unspecified), Texas, 20 July 1993, one male specimen (TTU 68630). Llano County (locality unspecified), Texas, 23 November 1993, one female specimen (TTU 68631); Llano County (locality unspecified), Texas, 2 June 1994, one female specimen (TTU 68632). Matagorda County (locality unspecified), Texas, 3 August 1993, one specimen of undetermined sex (TTU 68633). Nolan County (locality unspecified), Texas, 15 March 1994, one female specimen (TTU 68634). Orange, Orange County, Texas, 22 June 1995, two male specimens (TTU 68636-68637) and two female specimens (TTU 68635; TTU 68638). Robertson County (locality unspecified), Texas, 19 August 1994, one female specimen (TTU

68639). Somervell County (locality unspecified), Texas, 7 July 1993, one female specimen (TTU 68640). Tom Green County (locality unspecified), Texas, 28 January 1994, one female specimen (TTU 68641). Waller, Waller County, Texas, 20 April 1994, one female specimen (TTU 68642). Wise County (locality unspecified), Texas, 19 July 1994, one female specimen (TTU 68643). Wood County (locality unspecified), Texas, 19 August 1994, one female specimen (TTU 68644).

Lasiurus cinereus cinereus (Palisot de Beauvois)
Hoary Bat

The hoary bat ranges throughout Texas primarily as a fall-spring migrant (Schmidly 1991), but records are scattered. In an effort to fill in gaps in this species' distribution, specimens from Gillespie County in Central Texas and San Patricio County in South Texas are herein reported.

Material examined.—Gillespie County (locality unspecified), Texas, 29 April 1994, one female specimen (TTU 68646). San Patricio County (locality unspecified), Texas, 13 September 1994, one female specimen (TTU 68647).

Lasiurus intermedius H. Allen
Northern Yellow Bat

In Texas, the northern yellow bat is restricted to the eastern and southern portions of the state, where it is relatively uncommon (Schmidly 1991; Davis & Schmidly 1994). The first specimens of *L. intermedius* from Austin and Bee counties are herein reported. Both of these counties are well within the known range of this species. Based on Schmidly's (1991) distribution map, the specimen from Austin County is assigned to the subspecies *L. intermedius floridanus* (G. S. Miller), whereas the one from Bee County is referred to *L. intermedius intermedius* H. Allen.

Material examined.—Bee County (locality unspecified), Texas, 28 August 1993, one female specimen (TTU 68648). Bellville, Austin County, Texas, 26 September 1994, one male specimen (TTU 68649).

Lasiurus seminolus (Rhoads)
Seminole Bat

In Texas, specimens of the seminole bat are known only from the far east-central part of the state (Schmidly 1983; Schmidly 1991; Davis &

Schmidly 1994). This report documents new records for two counties, Fayette and Harrison. The record from Harrison County is at the northern limits of the species, whereas the one from Fayette County is adjacent to its western limits.

Material examined.—Fayette County (locality unspecified), Texas, 18 June 1994, one female specimen (TTU 68653). Harrison County (locality unspecified), Texas, 21 December 1993, one female specimen (TTU 68680).

Nycticeius humeralis humeralis (Rafinesque)
Evening Bat

The evening bat ranges throughout the eastern half of Texas (Schmidly 1991), but several counties within its range lack records for this species. During this study specimens were obtained from four of these counties: Harrison County in northeastern Texas, Orange and Austin counties in the east-central part of the state, and Brooks County in South Texas.

Material examined.—Bellville, Austin County, Texas, 26 September 1994, one male specimen (TTU 68661). Brooks County (locality unspecified), Texas, 1 September 1993, one female specimen (TTU 68662). Harrison County (locality unspecified), Texas, 4 December 1994, one female specimen (TTU 68663). Vidor, Orange County, Texas, 16 June 1995, one female specimen (TTU 68664).

Tadarida brasiliensis I. Geof. St.-Hilaire
Brazilian Free-tailed Bat

The Brazilian free-tailed bat is common in Texas and occurs statewide. However, there are numerous counties for which there is no record of this bat. During this study, specimens were acquired from 10 of these counties. They are: Dallam County in the Panhandle; Cass, Ellis, Fayette, Jefferson, and Panola counties in eastern Texas; Comanche and Coryell counties near the center of the state; Ward County in West Texas; and Starr County in South Texas. The specimens from Cass, Jefferson and Panola counties are referred to the subspecies *T. brasiliensis cynocephala* (Le Conte), whereas the remaining individuals are assigned to *T. brasiliensis mexicana* (Saussure) (Schmidly 1983; 1991).

Material examined.—Cass County (locality unspecified), Texas, 23 July 1993, one male specimen (TTU 68668). Comanche County

(locality unspecified), Texas, 11 August 1993, one male specimen (TTU 68667). Coryell County (locality unspecified), Texas, 10 June 1993, one female specimen (TTU 68669). Dallam County (locality unspecified), Texas, 23 September 1993, one female specimen (TTU 68675). Ellis County (locality unspecified), Texas, 20 August 1994, one male specimen (TTU 68670); Ellis County (locality unspecified), Texas, 17 September 1994, one specimen of undetermined sex (TTU 68671). Fayette County (locality unspecified), Texas, 10 September 1993, one male specimen (TTU 68672); Fayette County (locality unspecified), Texas, 11 September 1993, one male specimen (TTU 68673); Fayette County (locality unspecified), Texas, 23 August 1994, one specimen of undetermined sex (TTU 68674). Jefferson County (locality unspecified), Texas, no specific date 1995, one male specimen (TTU 68676). Carthage, Panola County, Texas, 23 March 1995, one female specimen (TTU 68666). Starr County (locality unspecified), Texas, 30 March 1993, one female specimen (TTU 68677). Ward County (locality unspecified), Texas, 27 September 1994, one female specimen (TTU 68678); Ward County (locality unspecified), Texas, 5 October 1994, one female specimen (TTU 68679).

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THE KARYOTYPE OF *MYOTIS LEVIS DINELLII*
(CHIROPTERA: VESPERTILIONIDAE)
FROM SOUTH AMERICA

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Abstract.—The karyotype of *Myotis levis dinellii* from Argentina was examined and determined to be $2N = 44$, (fundamental number 50). Karyotypic variation within the genus *Myotis* is also reviewed.

Myotis levis (Geoffroy 1824) is distributed in central Argentina, Uruguay, Bolivia and southeastern Brazil (Redford & Eisenberg 1992; Koopman 1993) where it inhabits a wide variety of habitats ranging from transition forests, moist Chaco Serrano forests to Monte Desert scrub (Mares et al. 1995). The systematic status of *Myotis levis* has remained unchanged since the major revision of the Neotropical members of the genus *Myotis* by La Val (1973). La Val (1973) recognized two subspecies; *M. levis levis* occurs in the eastern areas of central Argentina and *M. levis dinellii* which is found in the western part of this species range.

Reviews (Baker et al. 1982; Zima & Horacek 1985; Bickham et al. 1986; Mc Bee et al. 1986; Reina et al. 1994; Volleth & Heller 1994) have focused on the karyology of bats of the genus *Myotis* throughout the world. In mainland South America, 12 species of *Myotis* are known (Koopman 1993), but among the species that inhabit this continent, karyotypes have been described only for *M. nigricans* (Schinz 1821) by Bickham (1979) and *M. keaysi* Allen 1914 by Baker & Bickham (1980).

METHODS AND MATERIALS

A total of nine specimens of *Myotis levis dinellii* were collected with mist nets and by hand. The standard procedure of in-vivo colchicine mitotic arrest was used for obtaining chromosomes from bone marrow (Baker et al. 1982). In most cases the yeast stress method (Lee & Elder 1980) was used to obtain a higher mitotic index. Slides were produced by dropping the cell suspension from a height of 50-60 cm into a large drop of distilled water on the surface of the slide (Baker et al. 1982). Chromosome slides were observed and photographed, and the diploid number and chromosomal morphology were determined for each speci-



Figure 1. Karyotype of a male *Myotis levis dinellii* (RVP 180-TK 27903) from Argentina, La Pampa Province, Caleu Caleu Department, Almacén El 52.

men. Karyotypes were prepared in which autosomes were arranged in decreasing order of size and the X and Y placed as the last members of the series. The Y chromosome was tentatively identified as chromosome banding procedures were not made. Voucher specimens are deposited with the collections of The Museum at Texas Tech University (TTU) and the mammal collection of the Museo Provincial de Historia Natural (RVP), Santa Rosa, La Pampa, Argentina. Frozen tissue samples are deposited with the collections at Texas Tech University (TK).

Material examined.—Cordoba Province: Cruz del Eje Department, Palo Parado, one male specimen (TTU 64336-TK 40653); Rio Cuarto Department, Coronel Baigorria, Estancia San Gonzalo, five female specimens (TTU 64337-TK 40657, TTU 64338-TK 40658, TTU 64339-TK 40659, TTU 64341-TK 40662, TTU 64342-TK 40663). La Pampa Province; Caleu Caleu Department, Almacén El 52, three male specimens (TTU 64346-TK 27901, TTU 64347-TK 27902, RVP 180-TK 27903).

RESULTS AND CONCLUSIONS

The karyotype of *Myotis levis dinellii* ($2n = 44$, fundamental number 50) is composed of three pairs of large metacentric elements characteristic of the genus (Bickham 1979; Reina et al. 1994), a small

pair of metacentrics and seventeen pairs of acrocentrics. The smallest of the acrocentrics, the last three pairs, are barely discernable in their morphology. The X chromosome is a medium sized submetacentric and the Y chromosome is a small submetacentric (Figure 1).

This karyotype does not in general depart from those described for *M. nigricans* and *M. keaysi* except that *M. levis* has a Y chromosome that appears to be larger than the smallest pairs of autosomes and not the smallest chromosome as has been described for *Myotis nigricans* by Bickham (1979). Except for these minor variations, as found for the Y chromosome in the genus (Bickham 1979), *Myotis levis* further documents the chromosomal conservativeness characteristic of this genus and most of the Vespertilionidae (Baker & Bickham 1980).

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A TABLE OF VALUES FOR FISHER'S α LOG SERIES DIVERSITY INDEX

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ABSTRACT.—Fisher's α diversity index has been recommended for ecological studies by several authors, but its calculation requires the simultaneous solution of two equations. This can limit its use when many samples are involved. To overcome this limitation, a table of values for Fisher's α is presented and internet sources for obtaining the values are given.

A number of indices for measuring diversity of floras and faunas have been developed for use in ecological and biogeographic studies. Several authors (see Southwood 1978; Taylor 1978; Magurran 1988) have highly recommended use of the log series, or Fisher's α (Fisher et al. 1943) for this purpose. The following characteristics make α an attractive measure of diversity:

1. Low sensitivity to sample size (Kempton & Taylor 1974; Magurran 1988). Many diversity indices are sample size dependent, which limits comparisons between sets of unequal size.
2. Good discriminant ability. In statistical comparisons between replicated samples, α has been shown to yield a high variance ratio (F) when compared with other indices for the same data set (Kempton & Wedderburn 1978; Taylor 1978).
3. Robustness. Fisher's α is relatively insensitive to tails of the distribution (very sparse or abundant species), and its use has been recommended even when the data do not exactly fit the predicted distribution (Magurran 1988).
4. Demonstrated suitability in a variety of ecological applications (Southwood 1978).

On the basis of these attributes, Magurran (1988) stated that, while one should choose a diversity index suited for the questions being addressed in each specific investigation, α is "an excellent candidate for a universal diversity statistic." The log series model also has application in describing dispersal of individual organisms in space (Southwood 1978).

DISCUSSION AND RESULTS

Fisher's log series α may be extracted by maximum likelihood from the equation $S_T = \alpha \log_e(1 + N/\alpha)$, where S_T = the total number of species for a habitat area, and N = the number of individuals. (Southwood 1978). It may also be calculated from S (number of species in a sample), and N (number of individuals), by iterative solution of the equations $S = \alpha \log_e(1-x)$ and $N = \alpha x/(1-x)$, (Fisher et al. 1943). Alternatively, α may be read off a graph of its values relative to N and S (Fisher et al. 1943:52; Southwood 1978:431; Spellerberg 1991:120). However, this method is cumbersome for large numbers of samples, and inaccurate for small samples.

To avoid these computational problems for a large number of samples, a table of values was developed for finding α , given N and S using the mathematical software program Maple V® (Char et al. 1991a; 1991b). The procedure to do this presented in the section on Applications.

It would be unwieldy to produce a reference table for all possible values of N and S . As the relationship between α , N , and S , is nearly linear when N is much larger than S these values can be interpolated.

To reduce the size of the table and emphasize portions of the curve with the greatest change in slope, the table was constructed with reference to S and $N-S$, rather than for S and N . α was calculated for all values of S from 1 to 50 and $N-S$ from 1 to 10. Values in increments of 10 for each variable were calculated to 100, and increments of 100 to $N-S = 1000$ and $S = 500$. Values for $S = 1000$ were also calculated for illustrative purposes.

For $N-S < 10$ and $S < 50$, α can be obtained directly from Table 1. For $N-S > 10$ or $S > 50$, α must be interpolated. If $N-S > 10$ and $S > 50$, interpolation must be made on both dimensions. Formulae and examples for these interpolations are given in the section on Applications.

This study used these values in a list form to match the appropriate α value with sample N and S values using a Match Files or Merge procedure. For those wishing to perform similar operations, this list of values of N , S , $N-S$, and α is available in the file ALPHA.LST by anonymous FTP from site TTACS1.TTU.EDU, directory DOC, or from NHSBIG.INHS.UIUC.EDU, directory SOFTWARE.STATISTICAL.GENERAL, or on the World Wide Web at: http://nhsbig.inhs.uiuc.edu/general_stats/alpha.lst.

Table 1. Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=1$	2	3	4	5	6	7	8	9	10
$N-S=1$	0.796	2.622	5.453	9.284	14.116	19.949	26.782	34.615	43.448	53.281
2	0.525	1.592	3.167	5.245	7.824	10.905	14.486	18.568	23.150	28.233
3	0.428	1.235	2.388	3.878	5.705	7.867	10.363	13.193	16.358	19.856
4	0.376	1.051	1.989	3.184	4.632	6.333	8.286	10.489	12.944	15.649
5	0.343	0.935	1.743	2.759	3.980	5.403	7.028	8.855	10.883	13.112
6	0.319	0.856	1.576	2.471	3.538	4.775	6.182	7.757	9.500	11.410
7	0.302	0.797	1.453	2.261	3.218	4.322	5.571	6.966	8.505	10.187
8	0.288	0.752	1.359	2.101	2.975	3.978	5.109	6.367	7.753	9.264
9	0.277	0.715	1.284	1.974	2.782	3.706	4.745	5.898	7.163	8.541
10	0.267	0.685	1.223	1.871	2.626	3.487	4.451	5.518	6.688	7.959
20	0.219	0.535	0.921	1.371	1.879	2.445	3.066	3.742	4.471	5.253
30	0.198	0.473	0.802	1.178	1.596	2.056	2.555	3.093	3.668	4.280
40	0.185	0.437	0.734	1.069	1.439	1.842	2.277	2.741	3.236	3.759
50	0.176	0.413	0.689	0.998	1.336	1.703	2.096	2.515	2.959	3.427
60	0.170	0.395	0.656	0.946	1.262	1.604	1.968	2.355	2.763	3.193
70	0.165	0.381	0.630	0.906	1.206	1.528	1.871	2.234	2.616	3.017
80	0.161	0.370	0.610	0.874	1.161	1.468	1.794	2.138	2.500	2.879
90	0.157	0.361	0.593	0.848	1.124	1.419	1.731	2.060	2.406	2.766
100	0.154	0.353	0.578	0.826	1.093	1.377	1.678	1.995	2.327	2.673
200	0.137	0.308	0.499	0.705	0.925	1.156	1.399	1.652	1.914	2.185
300	0.129	0.287	0.463	0.650	0.849	1.058	1.276	1.501	1.735	1.975
400	0.124	0.274	0.440	0.617	0.803	0.998	1.201	1.411	1.627	1.850
500	0.120	0.265	0.424	0.593	0.771	0.956	1.149	1.348	1.553	1.763
600	0.117	0.258	0.411	0.575	0.746	0.925	1.110	1.301	1.497	1.699
700	0.115	0.252	0.402	0.560	0.727	0.900	1.079	1.264	1.454	1.648
800	0.113	0.247	0.394	0.549	0.711	0.880	1.054	1.233	1.418	1.606
900	0.111	0.243	0.387	0.539	0.697	0.862	1.033	1.208	1.388	1.572
1000	0.110	0.240	0.381	0.530	0.686	0.847	1.014	1.186	1.362	1.542

Table 1 (continued). Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=11$	12	13	14	15	16	17	18	19	20
$N-S=1$	64.114	75.947	88.780	102.613	117.446	133.280	150.113	167.946	186.779	206.613
2	33.815	39.898	46.481	53.563	61.146	69.229	77.812	86.895	96.478	106.561
3	23.687	27.852	32.351	37.183	42.349	47.848	53.681	59.847	66.346	73.179
4	18.604	21.810	25.266	28.973	32.930	37.137	41.594	46.301	51.258	56.465
5	15.541	18.171	21.001	24.032	27.263	30.694	34.325	38.157	42.189	46.421
6	13.488	15.734	18.146	20.726	23.473	26.387	29.468	32.715	36.130	39.711
7	12.014	13.985	16.099	18.356	20.757	23.301	25.988	28.818	31.792	34.908
8	10.902	12.666	14.556	16.571	18.712	20.978	23.370	25.887	28.530	31.297
9	10.032	11.635	13.350	15.177	17.115	19.166	21.327	23.601	25.986	28.482
10	9.332	10.806	12.381	14.056	15.833	17.710	19.687	21.766	23.944	26.223
20	6.087	6.974	7.912	8.902	9.944	11.037	12.181	13.376	14.621	15.918
30	4.928	5.612	6.333	7.088	7.879	8.705	9.565	10.461	11.391	12.355
40	4.310	4.890	5.498	6.132	6.794	7.483	8.199	8.941	9.710	10.505
50	3.918	4.433	4.970	5.530	6.113	6.717	7.344	7.992	8.662	9.354
60	3.642	4.112	4.601	5.110	5.638	6.185	6.751	7.335	7.938	8.559
70	3.436	3.872	4.326	4.797	5.285	5.790	6.311	6.849	7.402	7.972
80	3.273	3.684	4.111	4.553	5.010	5.483	5.970	6.471	6.987	7.518
90	3.142	3.533	3.937	4.356	4.789	5.235	5.695	6.168	6.654	7.153
100	3.033	3.406	3.793	4.193	4.606	5.031	5.468	5.918	6.380	6.853
200	2.466	2.755	3.052	3.357	3.670	3.990	4.318	4.654	4.996	5.346
300	2.223	2.477	2.738	3.005	3.278	3.557	3.842	4.132	4.428	4.729
400	2.079	2.313	2.553	2.798	3.048	3.303	3.563	3.828	4.097	4.371
500	1.979	2.200	2.426	2.656	2.891	3.131	3.374	3.622	3.873	4.129
600	1.905	2.116	2.332	2.551	2.775	3.003	3.234	3.469	3.708	3.951
700	1.847	2.050	2.258	2.469	2.684	2.903	3.125	3.351	3.580	3.812
800	1.799	1.996	2.197	2.402	2.610	2.822	3.036	3.255	3.476	3.700
900	1.760	1.951	2.147	2.346	2.548	2.754	2.963	3.174	3.389	3.606
1000	1.726	1.913	2.104	2.298	2.496	2.696	2.900	3.106	3.315	3.527

Table 1 (continued). Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=21$	22	23	24	25	26	27	28	29	30
$N-S=1$	227.446	249.279	272.112	295.946	320.779	346.612	373.446	401.279	430.112	459.945
2	117.144	128.227	139.810	151.894	164.477	177.560	191.143	205.226	219.810	234.893
3	80.345	87.844	95.677	103.844	112.343	121.176	130.343	139.842	149.675	159.842
4	61.923	67.630	73.588	79.796	86.253	92.961	99.919	107.127	114.584	122.292
5	50.853	55.485	60.317	65.349	70.582	76.014	81.647	87.479	93.512	99.744
6	43.459	47.374	51.456	55.705	60.120	64.702	69.451	74.367	79.449	84.698
7	38.168	41.571	45.116	48.805	52.636	56.611	60.729	64.989	69.392	73.939
8	34.190	37.209	40.352	43.620	47.014	50.533	54.177	57.946	61.840	65.859
9	31.089	33.808	36.639	39.580	42.633	45.798	49.073	52.460	55.958	59.567
10	28.602	31.082	33.662	36.342	39.122	42.002	44.983	48.064	51.245	54.526
20	17.265	18.663	20.112	21.611	23.161	24.761	26.412	28.113	29.864	31.665
30	13.354	14.387	15.454	16.555	17.691	18.860	20.063	21.301	22.572	23.877
40	11.327	12.174	13.048	13.948	14.873	15.825	16.802	17.805	18.834	19.888
50	10.067	10.801	11.557	12.334	13.132	13.950	14.790	15.651	16.532	17.434
60	9.199	9.856	10.531	11.225	11.936	12.665	13.412	14.176	14.958	15.758
70	8.558	9.159	9.777	10.409	11.058	11.722	12.401	13.096	13.806	14.531
80	8.062	8.621	9.194	9.780	10.381	10.995	11.623	12.265	12.920	13.589
90	7.665	8.190	8.728	9.278	9.840	10.416	11.003	11.603	12.215	12.839
100	7.339	7.836	8.345	8.865	9.397	9.940	10.495	11.061	11.637	12.225
200	5.702	6.066	6.436	6.813	7.196	7.586	7.983	8.386	8.795	9.211
300	5.035	5.347	5.664	5.985	6.312	6.644	6.980	7.322	7.668	8.018
400	4.649	4.932	5.218	5.509	5.804	6.104	6.407	6.714	7.025	7.340
500	4.389	4.652	4.919	5.190	5.464	5.741	6.023	6.307	6.595	6.887
600	4.197	4.446	4.699	4.955	5.214	5.476	5.742	6.010	6.282	6.556
700	4.048	4.286	4.528	4.773	5.021	5.271	5.525	5.781	6.040	6.301
800	3.927	4.157	4.390	4.626	4.864	5.106	5.349	5.596	5.845	6.096
900	3.827	4.050	4.276	4.504	4.735	4.968	5.204	5.443	5.683	5.926
1000	3.742	3.959	4.178	4.400	4.625	4.852	5.081	5.313	5.546	5.782

Table 1 (continued). Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=31$	32	33	34	35	36	37	38	39	40
$N-S=1$	490.779	522.612	555.445	589.279	624.112	659.945	696.779	734.612	773.445	813.279
2	250.476	266.559	283.142	300.226	317.809	335.892	354.475	373.559	393.142	413.225
3	170.341	181.175	192.341	203.841	215.674	227.840	240.340	253.173	266.340	279.840
4	130.250	138.458	146.916	155.624	164.582	173.790	183.248	192.956	202.914	213.122
5	106.177	112.810	119.643	126.675	133.908	141.341	148.974	156.807	164.840	173.073
6	90.114	95.696	101.446	107.361	113.444	119.693	126.109	132.692	139.442	146.358
7	78.628	83.460	88.435	93.553	98.814	104.218	109.765	115.455	121.287	127.263
8	70.004	74.273	78.668	83.187	87.832	92.602	97.496	102.516	107.661	112.931
9	63.287	67.119	71.062	75.116	79.281	83.557	87.945	92.444	97.053	101.775
10	57.907	61.388	64.969	68.651	72.432	76.314	80.296	84.378	88.559	92.841
20	33.517	35.420	37.372	39.375	41.428	43.531	45.685	47.888	50.142	52.446
30	25.216	26.589	27.995	29.435	30.909	32.417	33.958	35.533	37.142	38.784
40	20.968	22.074	23.205	24.361	25.544	26.751	27.984	29.243	30.527	31.836
50	18.357	19.301	20.266	21.250	22.256	23.282	24.329	25.396	26.484	27.592
60	16.575	17.409	18.261	19.131	20.017	20.921	21.843	22.781	23.737	24.710
70	15.271	16.027	16.798	17.583	18.384	19.200	20.031	20.876	21.737	22.613
80	14.271	14.966	15.676	16.398	17.134	17.883	18.645	19.420	20.209	21.010
90	13.475	14.124	14.784	15.456	16.141	16.837	17.546	18.266	18.998	19.742
100	12.825	13.435	14.056	14.688	15.331	15.985	16.649	17.325	18.011	18.708
200	9.633	10.061	10.496	10.936	11.383	11.836	12.294	12.759	13.230	13.707
300	8.374	8.734	9.098	9.468	9.841	10.219	10.602	10.988	11.380	11.775
400	7.658	7.981	8.307	8.637	8.970	9.307	9.648	9.992	10.340	10.691
500	7.181	7.479	7.780	8.085	8.392	8.703	9.016	9.333	9.653	9.976
600	6.834	7.114	7.398	7.684	7.972	8.264	8.558	8.856	9.155	9.458
700	6.566	6.833	7.102	7.375	7.649	7.926	8.206	8.488	8.773	9.060
800	6.350	6.607	6.865	7.127	7.390	7.656	7.924	8.194	8.467	8.742
900	6.172	6.419	6.669	6.922	7.176	7.432	7.691	7.952	8.215	8.480
1000	6.021	6.261	6.504	6.748	6.995	7.243	7.494	7.747	8.002	8.258

Table 1 (continued). Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=41$	42	43	44	45	46	47	48	49	50
$N-S=1$	854.112	895.945	938.779	982.612	1027.445	1073.278	1120.112	1167.945	1216.778	1266.612
2	433.808	454.892	476.475	498.558	521.141	544.225	567.808	591.891	616.475	641.558
3	293.673	307.839	322.339	337.173	352.339	367.839	383.672	399.839	416.339	433.172
4	223.580	234.288	245.247	256.455	267.913	279.621	291.579	303.787	316.245	328.953
5	181.506	190.139	198.972	208.005	217.238	226.671	236.304	246.137	256.170	266.403
6	153.440	160.690	168.106	175.689	183.439	191.355	199.438	207.687	216.104	224.686
7	133.381	139.642	146.046	152.593	159.283	166.116	173.092	180.210	187.472	194.876
8	118.326	123.846	129.491	135.261	141.156	147.176	153.321	159.591	165.986	172.507
9	106.607	111.550	116.605	121.770	127.047	132.435	137.934	143.545	149.266	155.099
10	97.223	101.706	106.288	110.970	115.752	120.634	125.616	130.699	135.881	141.164
20	54.800	57.205	59.659	62.164	64.718	67.323	69.978	72.683	75.438	78.244
30	40.459	42.169	43.912	45.688	47.498	49.342	51.219	53.129	55.074	57.051
40	33.171	34.531	35.916	37.327	38.763	40.224	41.711	43.222	44.760	46.322
50	28.721	29.870	31.039	32.229	33.439	34.670	35.921	37.192	38.483	39.795
60	25.700	26.707	27.732	28.773	29.832	30.908	32.001	33.110	34.237	35.381
70	23.503	24.408	25.328	26.263	27.213	28.177	29.156	30.150	31.159	32.182
80	21.825	22.653	23.494	24.348	25.216	26.096	26.989	27.895	28.814	29.746
90	20.497	21.264	22.044	22.834	23.637	24.451	25.277	26.114	26.963	27.824
100	19.416	20.134	20.863	21.603	22.353	23.114	23.885	24.667	25.460	26.263
200	14.189	14.678	15.172	15.672	16.178	16.690	17.207	17.731	18.260	18.794
300	12.175	12.579	12.987	13.400	13.817	14.238	14.663	15.092	15.525	15.963
400	11.046	11.404	11.766	12.131	12.500	12.872	13.247	13.625	14.007	14.393
500	10.302	10.630	10.962	11.297	11.634	11.974	12.318	12.664	13.012	13.364
600	9.763	10.071	10.381	10.694	11.009	11.327	11.648	11.971	12.296	12.624
700	9.350	9.641	9.936	10.232	10.531	10.832	11.136	11.441	11.749	12.059
800	9.019	9.298	9.580	9.863	10.149	10.437	10.727	11.019	11.313	11.609
900	8.747	9.016	9.287	9.560	9.835	10.112	10.391	10.671	10.954	11.239
1000	8.517	8.777	9.040	9.304	9.570	9.838	10.108	10.379	10.652	10.927

Table 1 (continued). Values of Fisher's log series α for the number of species (S) and number of individuals minus the number of species ($N-S$) in a sample.

	$S=60$	70	80	90	100	200	300	400	500	1000
$N-S=1$	1819.945	2473.278	3226.611	4079.945	5033.278	20066.611	45099.945	80133.278	125166.611	500333.278
2	919.891	1248.224	1626.557	2054.890	2533.223	10066.556	22599.889	40133.223	62666.556	250333.222
3	619.838	839.837	1093.170	1379.836	1699.836	6733.168	15099.834	26799.834	41833.167	166999.834
4	469.785	635.618	826.450	1042.283	1283.116	5066.447	11349.779	20133.112	31416.445	125333.112
5	379.734	513.066	666.398	839.730	1033.063	4066.393	9099.725	16133.057	25166.390	100333.056
6	319.683	431.348	559.679	704.678	866.344	3399.672	7599.670	13466.336	20999.669	83666.334
7	276.776	372.964	483.438	608.198	747.244	2923.428	6528.187	11561.519	18023.424	71761.517
8	244.585	329.164	426.244	535.825	657.907	2566.231	5724.562	10132.894	15791.226	62832.891
9	219.536	295.087	381.750	479.525	588.412	2288.401	5099.508	9021.728	14055.060	55888.391
10	199.489	267.816	346.145	434.475	532.806	2066.125	4599.454	8132.785	12666.117	50332.781
20	109.051	144.865	185.683	231.504	282.327	1065.611	2348.927	4132.251	6415.579	25332.234
30	78.669	103.631	131.935	163.577	198.556	731.788	1598.417	2798.397	4331.718	16998.359
40	63.331	82.856	104.892	129.437	156.487	564.654	1222.923	2131.222	3289.534	12831.157
50	54.028	70.281	88.549	108.828	131.115	464.207	997.445	1730.727	2664.028	10330.627
60	47.754	61.819	77.567	94.996	114.103	397.112	846.981	1463.576	2246.864	8663.436
70	43.219	55.713	69.657	85.045	101.875	349.083	739.388	1272.627	1948.758	7472.440
80	39.776	51.087	63.672	77.526	92.644	312.975	658.594	1129.308	1725.065	6579.069
90	37.065	47.452	58.976	71.631	85.415	284.818	595.669	1017.745	1550.985	5884.115
100	34.869	44.512	55.184	66.878	79.591	262.230	545.256	928.414	1411.635	5328.056
200	24.451	30.662	37.416	44.706	52.526	159.181	316.654	524.460	782.436	2823.270
300	20.560	25.551	30.926	36.676	42.796	123.549	238.772	387.837	570.513	1985.562
400	18.422	22.766	27.413	32.356	37.588	105.052	198.880	318.362	463.218	1564.873
500	17.032	20.965	25.153	29.589	34.267	93.541	174.344	275.920	397.953	1311.151
600	16.037	19.682	23.550	27.633	31.926	85.592	157.578	247.098	353.813	1141.025
700	15.280	18.710	22.339	26.160	30.167	79.722	145.309	226.126	321.817	1018.748
800	14.679	17.940	21.383	25.000	28.785	75.177	135.887	210.105	297.463	926.436
900	14.187	17.311	20.603	24.055	27.663	71.533	128.388	197.415	278.238	854.145
1000	13.774	16.784	19.952	23.268	26.728	68.533	122.255	187.081	262.631	795.905

APPLICATIONS

The following are given in the interest of providing examples of various applications of the Fisher's α log series.

Application 1. Maple V® procedure to calculate a given N and S (written by Justin Ortiz of the Texas Tech Advanced Technology Learning Center).

```

find_alpha := proc()
  if nargs=2           # Procedure requires two input values.
  then
    n1 := args[1];      # Number of individuals in sample.
    s1 := args[2];      # Number of species in sample.

    n := (a*x/(1-x)=n1);
    s := (-a*log(1-x)=s1);

                                # Solve for 'a' and 'x'.

    f:=fsolve({s,n},{a,x},{a=0..200000,x=0.001..1},fulldigits);

                                # fsolve will return two operands.
    a1 := op(2,op(1,f)); # The value for 'a' is in the second
                          # operand of the first operand.

    x1 := op(2,op(2,f)); # The value for 'x' is in the second
                          # operand of the second operand.
                          # The fsolve in Maple V on the VAX
                          # 6520 and Maple V.2 on the DecPc
                          # 450ST will sometimes return the
                          # answers in the wrong order. The next
                          # 'if' statement will check and reorder
                          # the answers.

    if op(1,op(1,f)) = `x`
    then
      a2 := a1;
      a1 := x1;
      x1 := a2;
    fi;
    lprint(n,s,a1,x1);
else

```

```

lprint(`find_alpha(n,s);`);

fi;
end;

```

This procedure calculated α and x with 10 digit precision when called with statements containing the desired values of N and S : $\text{find_alpha}(N,S);$, e.g.: $\text{find_alpha}(107,21);$. The procedure did not calculate all values for a when run on the VAX and Macintosh versions of Maple, but did so on the Windows implementation.

Application 2. Formulae for interpolating to find α from table values. For increased precision, log-transformed interpolation is performed with regards to α and N (but not S).

A. Interpolating for an intermediate value of S when $N-S$ corresponds to a table value:

$$\alpha = \exp\left(\ln(\alpha_{LB}) + \left(\frac{S_{IN} - S_{LB}}{S_{UB} - S_{LB}}\right)(\ln(\alpha_{UB}) - \ln(\alpha_{LB}))\right)$$

Where $\alpha_{LB} = \alpha$ for S_{LB} , read from the table.

$S_{IN} = S$ for interpolation

S_{LB} = table value of S less than S_{IN} (i.e. lower bound)

S_{UB} = table value of S greater than S_{IN} (i.e. upper bound)

$\alpha_{UB} = \alpha$ for S_{UB} , read from the table.

Example: $N = 74$, $S = 68$, $N-S = 6$ (calculated value = 407.681).

$$\alpha_{74,68} = \exp\left(\ln(319.683) + \left(\frac{68-60}{70-60}\right)(\ln(431.348) - \ln(319.683))\right)$$

$$\alpha_{74,68} = \exp\left(5.767 + \left(\frac{8}{10}\right)(6.067 - 5.767)\right)$$

$$\alpha_{74,68} = \exp(5.767 + (0.8)(0.300))$$

$$\alpha_{74,68} = \exp(6.007)$$

$$\alpha_{74,68} = 406.262$$

B. Interpolating for an intermediate value of N and $N-S$ when S corresponds to a table value:

$$\alpha = \exp\left(\ln(\alpha_{LB}) + \left(\frac{\ln(N_{IN}) - \ln(N_{LB})}{\ln(N_{UB}) - \ln(N_{LB})}\right)(\ln(\alpha_{UB}) - \ln(\alpha_{LB}))\right)$$

Where $\alpha_{LB} = \alpha$ for $N_{LB}-S$, read from the table.

$S_{IN} = S$ for interpolation

$N_{LB} = N$ corresponding to the table value of $N-S$ less than $N_{LB}-S$ (i.e. lower bound)

$N_{UB} = N$ corresponding to the table value of $N-S$ greater than $N_{UB}-S$ (i.e. upper bound)

$\alpha_{UB} = \alpha$ for $N_{UB}-S$, read from the table.

Example: $N = 88$, $S = 16$, $N-S = 72$ (calculated value = 5.723).

$$\alpha_{88,16} = \exp\left(\ln(5.790) + \left(\frac{\ln(72+16) - \ln(70+16)}{\ln(80+16) - \ln(70+16)}\right)(\ln(5.483) - \ln(5.790))\right)$$

$$\alpha_{88,16} = \exp\left(1.756 + \left(\frac{4.477 - 4.454}{4.564 - 4.454}\right)(1.702 - 1.756)\right)$$

$$\alpha_{88,16} = \exp\left(1.756 + \left(\frac{0.023}{0.110}\right)(-0.054)\right)$$

$$\alpha_{88,16} = \exp(1.756 + (0.209)(-0.054))$$

$$\alpha_{88,16} = \exp(1.745)$$

$$\alpha_{88,16} = 5.724$$

C. Interpolating for intermediate values of N , $N-S$, and S . This can be done as a two-step process using the equations given above. α is interpolated for the upper and lower boundaries of one factor, for the desired value of the second. Then these values are used to interpolate for the second factor.

Example: $N = 451$, $S = 83$, $N-S = 368$ (calculated value = 29.869).

First find α for:

$N = 448$, $S = 80$, $N-S=368$ and $N = 458$, $S = 90$, $N-S = 368$

$$\alpha_{448,80} = \exp\left(\ln(30.926) + \left(\frac{\ln(368+80) - \ln(300+80)}{\ln(400+80) - \ln(300+80)}\right)(\ln(27.413) - \ln(30.926))\right) = 28.407$$

$$\alpha_{458,90} = \exp\left(\ln(36.676) + \left(\frac{\ln(368+90) - \ln(300+90)}{\ln(400+90) - \ln(300+90)}\right)(\ln(32.356) - \ln(36.676))\right) = 33.578$$

Then:

$$\alpha_{451,83} = \exp\left(\ln(28.407) + \left(\frac{83-80}{90-80}\right)(\ln(33.578) - \ln(28.407))\right) = 29.868$$

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OCCURRENCE OF THE ENDANGERED PRONGHORN
ANTILOCAPRA AMERICANA PENINSULARIS IN COYOTE DIETS
FROM NORTHWESTERN MEXICO

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Abstract.—The stomach contents of 50 specimens of the coyote *Canis latrans* from the Vizcaíno Desert of northwestern Mexico were analyzed to determine predation level of this species upon the endangered population of Baja California pronghorn. Results indicate that coyote diets consisted primarily of rodents and lagomorphs. The incidence of pronghorn ingestion was found to be only four percent. Predation by *Canis latrans* is not considered to represent a significant threat in the decline of this endangered subspecies of antelope.

Resumen.—El contenido de los estómagos de 50 espécímenes del coyote *Canis latrans* del Desierto de Vizcaíno del norte de México fue analizado para determinar el índice de la caza predatoria de esta especie sobre los berrendos de Baja California. Los resultados indican que los coyotes principalmente comían roedores y lagomorfos. La incidencia de la ingestión del berrendo peninsular era solamente de cuatro por ciento. La caza predatoria del *Canis latrans* no es una amenaza significativa en la declinación del berrendo peninsular.

Antilocapra americana peninsularis is one of five subspecies of pronghorn antelope native to North America (Hall 1981). It is endemic to the Baja Peninsula of México where it is considered to be this country's most endangered mammalian subspecies (González-Romero et al. 1991). It has been proposed that one of the major constraining factors to the restoration of populations of this endangered subspecies in the Vizcaíno Desert is predation by coyotes, especially during the winter fawning period (SEDUE 1984; Jaramillo et al. 1985). While this proposal appears plausible, there is a lack of experimental data to support this premise as it relates to the pronghorn population of the Baja Peninsula of México. Instead, it appears to be based solely upon the report of pronghorn predation by coyotes in the United States by Connolly (1978).

This investigation was undertaken in order to determine the level of coyote predation upon pronghorn populations in the Vizcaíno Desert of the Baja Peninsula of northwestern México.

STUDY AREA

The study area is located on the west coast of the Vizcaíno Desert, Baja California Sur, México ($26^{\circ} 30'$ to 28° N and 114° to 115° W).

The climate is dry with an annual precipitation ranging from 50.13 to 83.69 mm. The average annual temperature ranges from 18 to 22° C. Altitude of the area varies from sea level to 200 m. Primary vegetational types as reported by León et al. (1991) include: saltbush with species of *Atriplex* and *Salicornia*; halophyte scrub with species of *Ambrosia*, *Bursera*, *Bouteloa* and *Muhlenbergia*; coastal dunes with species of *Abronia*, *Dalea* and *Plantago*, and the Sarco-crasicaule scrub with species of *Acacia*, *Jatropha*, *Larrea*, *Opuntia* and *Yucca*.

METHODS AND MATERIALS

Fifty coyote specimens were obtained during the winter of 1985 as the result of a federal program designed to control populations of this predator in the Vizcaíno Desert. Only specimens collected from January to March were examined. These months represent both the time of winter concentration of pronghorns in the area as well as the fawning period (SEDUE 1984; Jaramillo et al. 1985). This is the only area of the Vizcaíno Desert where coyote and pronghorn populations are sympatric during the winter months. A census of the area during the period of winter concentration in 1985 revealed a population of 70 individuals (SEDUE 1986) of *Antilocapra americana peninsularis*.

Coyote traps were baited with fish carcasses, placed two km apart at sunset and checked each morning. The study area consisted of a total of 25 km². Stomachs were removed and washed with water. Laboratory analysis basically followed those of Korschgen (1980). Contents were separated, classified, and weighed. A reference collection of plants, mammals, reptiles and birds of the area was used to identify stomach contents. The percent of each food item was calculated on a per stomach basis; percent occurrence refers to the number of stomachs in which the presence of the specific food item was recorded.

RESULTS AND DISCUSSION

The results (Table 1) of this study reveal that the primary dietary items of wintering coyotes in the Vizcaíno Desert of México are rodents and lagomorphs. These two groups of prey species together constituted 73.7% of the total weight of material removed from coyote stomachs. Remains of *Dipodomys* were present in 40%, *Thomomys* in 20%, and *Lepus* in 10% of all coyotes examined. Plant material, reptiles, and arthropods were also recovered as common food items.

Table 1. Results of stomach content analysis of 50 specimens of *Canis latrans* from the Vizcaíno Desert of the Baja Peninsula of México.

	Percent Occurrence	Weight Recovered	Percent of Total Weight
Rodents			
<i>Dipodomys</i> sp.	40%	766.74 g	24.4%
<i>Thomomys umbrinus</i>	20%	434.07 g	13.8%
<i>Peromyscus</i> sp.	6%	385.40 g	12.3%
<i>Neotoma lepida</i>	4%	237.32 g	7.6%
<i>Perognathus</i> sp.	2%	204.87 g	6.5%
		<u>2,028.40 g</u>	<u>64.6%</u>
Lagomorphs			
<i>Lepus</i> sp.	10%	171.42 g	5.4%
<i>Silvilagus</i> sp.	4%	116.68 g	3.7%
		<u>288.10 g</u>	<u>9.1%</u>
Reptiles			
<i>Cnemidophorus</i> sp.	18%	25.12 g	0.8%
<i>Sceloporus magister</i>	6%	18.32 g	0.6%
<i>Phrynosoma coronatum</i>	6%	22.80 g	0.7%
<i>Colubridae</i> sp.	4%	16.66 g	0.5%
		<u>82.90 g</u>	<u>2.6%</u>
Arthropods			
<i>Diptera</i>	12%	21.71 g	0.7%
<i>Coleoptera</i>	10%	19.18 g	0.6%
<i>Orthoptera</i>	6%	4.87 g	0.2%
<i>Chilopoda</i>	6%	10.89 g	0.3%
<i>Lepidoptera</i>	2%	6.65 g	0.2%
		<u>63.30 g</u>	<u>2.0%</u>
Pronghorn antelope	4%	0.60 g	<0.1%
Birds	8%	21.60 g	0.7%
Domestic livestock	4%	56.30 g	1.8%
Gray Whale	4%	417.35 g	13.3%
Plant material	30%	85.60 g	2.7%
Sand	18%	24.80 g	0.8%
Unidentified	14%	68.80 g	2.2%

The occurrence of pronghorn antelope was found to be quite low in comparison with rodents and lagomorphs. Only two coyote specimens (4%) were found to contain remains of *Antilocapra americana peninsularis*. It was not ascertained whether pronghorn consumption represented coyote predation or carrion ingestion.

One noteworthy result of this study is the first documentation of coyote consumption of the gray whale *Eschrichtius robustus*. Laguna Ojo de Liebre (Scammon's Lagoon), which constitutes a part of the northern border of the study area, is a known habitat of the gray whale (Maravilla 1991). Although not documented by field observations, this report of consumption of whale carrion is almost certainly the result of coyotes feeding upon the remains of a stranded or beached individual.

CONCLUSIONS

While this study does in fact document evidence of pronghorn consumption by coyotes in the Vizcaíno Desert, the frequency of occurrence was found to be quite low and the amount consumed relatively small. The decline of populations of pronghorns in this area of the Baja Peninsula cannot be attributed solely to the occurrence of coyote predation during the fawning season. Other parameters such as the effects of habitat loss and unauthorized hunting must be considered and investigated.

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GENERAL NOTES

PREHISTORIC EVIDENCE FOR THE USE OF *CHENOPODIUM* (GOOSEFOOT) FROM THE HUECO BOLSON OF WEST TEXAS

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Utilized among early indigenous groups throughout the American Southwest and northern Mexico, seeds and greens of the genus *Chenopodium* (goosefoot) were frequently gathered for their medicinal and nutritive value (Castetter & Underhill 1935; Castetter & Opler 1936; Ebeling 1986). The greens were often gathered and mixed with other foods (e.g., meat) to form soups and the seeds were parched and ground into flour.

Evidence for the prehistoric use of *Chenopodium* in the semi-arid Hueco Bolson, located in far western Texas, is limited in open-air sites, and confined almost exclusively to the recovery of charred seeds. While some archaeological evidence for the use of *Chenopodium* and other chenopods has been documented (Miller 1990; Whalen 1994), these occurrences tend to be confined to the larger sites that exhibit a number of pithouses or adobe pueblo rooms, formalized midden areas, substantial numbers and diversity of associated artifacts. Although chenopods have been recovered at smaller, more ephemeral sites (see for example O'Laughlin 1988), the quantities are typically very limited (e.g., <5 seeds).

Recently, over 50 charred and broken *Chenopodium* seeds were recovered from float samples of fill (approximately two liter volume) from the floor area of an ephemeral grass/thatch hut (Feature 6, 41EP3173) excavated in the central Hueco Bolson (Holloway 1994; Leach et al. 1996). The feature produced radiocarbon dates of 1250 ± 90 and 1410 ± 70 YBP, and is thought to represent the remains of a short-term, seasonal occupation. The feature has an estimated floor area of 3.7 m^2 that is consistent with other small, ephemeral structures located throughout the central basin (Whalen 1994). The only other

possible economic plants recovered from the site includes a single *Zea mays* kernel and coniferous hull fragments from other features spatially associated with the structure. *Prosopis* (mesquite), *Pinus* (pinyon), *Atriplex/Sarcobatus* (four-wing salt-bush/greasewood), and *Quercus* (oak) wood charcoal were also identified at the site, but are considered to be sources for fuelwood or construction materials.

While a few of the seeds recovered were intact, the majority were broken. The broken seeds may constitute direct evidence that the *Chenopodium* seeds were being processed, presumably by grinding, to produce flour (Castetter & Underhill 1935; Ebeling 1986:478). The grinding of the seeds is indirectly supported by numerous fragments of ground stone recovered from the immediate area around the structure. While broken seeds may occur as a result of numerous cultural and natural processes (Wetterstrom 1978:231), the high proportion of broken seed coats from archaeological assemblages strongly argues for cultural behavior.

Given the difficulty in distinguishing the seeds of *Chenopodium* from other taxa in the family Amaranthaceae, and problems of preservation and identification in archaeological contexts (Minnis 1981), seeds of *Chenopodium* are rarely recovered, and less frequently identified in open-air sites. However, evidence of *Chenopodium* use is commonly reported in coprolite analyses (Stock 1983; Sobolik 1988; 1990), plant macro fossil analysis (Dering 1979), and pollen studies (Holloway 1983; Bryant 1986) from cave deposits east of the Hueco Bolson. The ubiquity of *Chenopodium* in cave deposits demonstrates its importance among prehistoric groups and suggests this plant may have been more commonly used by the prehistoric populations in the basin lowlands of far western Texas than is evidenced in the archaeological record.

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WINTER UTILIZATION OF BOX CULVERTS BY VESPERTILIONID BATS IN SOUTHEAST TEXAS

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A preliminary survey of 15 concrete box culverts as potential roost sites for bats was conducted on 27 January 1995. These culverts are located in Freestone, Leon, Madison and Walker counties in SE Texas and are positioned along Interstate Highway 45. The majority of the culverts varied from 60 to 120 m in length, ranged in height from 1.2 to 2.2 m, and measured 1.2 to 1.8 m in width. Most culverts contained standing water and had vegetation surrounding the entrance. Eight of the 15 culverts examined contained bats.

Three species of vespertilionid bats, *Myotis austroriparius* (southeastern myotis), *Pipistrellus subflavus subflavus* (eastern pipistrelle), and *Eptesicus fuscus fuscus* (big brown bat), were found roosting among some of the culverts. Two of the species, *P. subflavus* and *M. austroriparius*, represent a new county record and range extension, respectively. Specimens representing new records were prepared as vouchers and are deposited in the Texas Cooperative Wildlife Collection (TCWC) at Texas A&M University.

Pipistrellus subflavus (TCWC 52872, 52873, 52874) was by far the most common species encountered; it was found in all four counties and in all culverts where bats were observed. Although this species has been reported for Freestone, Walker and Brazos counties (Schmidly 1991; Nedbal et al. 1994), the Madison and Leon county observations represent new county records. Individuals were observed roosting separately and in clusters throughout the culverts, with most bats either on the culvert ceiling or in the angle between the wall and ceiling. Although Barbour & Davis (1969) indicated that the eastern pipistrelle rarely occurs in buildings, this species appears to be utilizing the man-made culverts as a winter roost. *Pipistrellus subflavus* is known to occupy winter hibernation sites, with the length of hibernation being variable (Barbour & Davis 1969; Brack & Twente 1985). During this study individuals observed from January through most of March appeared to be in torpor. These bats were difficult to arouse and some were coated

with water droplets and spider webs. These observations are similar to those made by Barbour & Davis (1969) for hibernating eastern pipistrelles. The number of specimens found in the various culverts ranged from 1 to 254, and in one series of two parallel culverts 410 individuals were observed. By the first week in April most of the eastern pipistrelles had disappeared. They remained absent from the culverts throughout the summer of 1995, and began reappearing during the first week of September 1995. Although an ecological study of *P. subflavus* was conducted in Louisiana (Jones & Suttkus 1973), there is little information on yearly activities of these bats in the southern portion of their range.

The presence of *M. austroriparius* (TCWC 52871) in Leon, Freestone and Walker counties represents a range extension. The nearest previously reported record for this species is approximately 110-180 km to the SE in Tyler County, Texas (Schmidly 1991). The specific localities where this species was observed are as follows: 19 km N of Huntsville, Walker County, Texas; 4.8 km N of Buffalo, Freestone County, Texas; Buffalo and 3.2 km S of Buffalo, Leon County, Texas. This species was found in association with *P. subflavus* at all four localities. Unlike the eastern pipistrelle, individuals of *M. austroriparius* did not appear to be in torpor, as they were alert and flew when approached. Additional surveys conducted during the period from January to October 1995 suggest that this species utilizes the culverts as day roosts throughout the year.

The only other species observed utilizing the culverts was *Eptesicus fuscus*. Two clusters of three females were found at the Walker County locality during January and February but were not observed during any of the subsequent surveys. Currently, research is being conducted on a series of culverts with and without bats in an effort to learn more about both the seasonal use of these culverts by bats and the factors that make some culverts more suitable than others as roost sites for bats.

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* * * * *

A RANGE EXTENSION FOR THE LEAST SHREW (*Cryptotis parva*) IN WEST-CENTRAL TEXAS

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Knowledge of the distribution of the least shrew, *Cryptotis parva*, in Texas and New Mexico has increased markedly since the publication of Hall (1981). Hoditschek et al. (1985) reported the first records extending the known distribution of this species into New Mexico. Owen & Hamilton (1986) reported a second specimen from New Mexico and summarized the distribution of *C. parva* on the Llano Estacado. In central Texas, four specimens were recently reported from Brownwood, Brown County, by Pitts & Smolen (1988). Other records for west-central Texas include Val Verde (Bailey 1905), Fisher (Jones et al. 1991) and Taylor (Davis & Schmidly 1994) counties. This report documents specimens from three localities in Tom Green County, extending the known distribution of *C. parva* in central Texas considerably westward.

On 22 July 1993, a female specimen of *Cryptotis parva* was brought to the Angelo State Natural History Collections (ASNHC) of Angelo State University. The specimen (ASNHC 8192) had been caught by a domestic cat at 1.5 mi S, 3 mi E of San Angelo, Tom Green County, Texas. A survey of ASNHC holdings produced two additional specimens of *C. parva*, both males, from Tom Green County. One had been

collected from 3.3 mi N, 3.6 mi W of San Angelo on 15 October 1991 (ASNHC 7582) in an ungrazed mesquite pasture. Collections from this general area in 1969 and 1974 included only the desert shrew, *Notiosorex crawfordi*. The second specimen of *Cryptotis parva* had been collected in an area of similar habitat at 3 mi N, 1.5 mi W of Mereta on 7 August 1992 (ASNHC 8191).

These records for Tom Green County extend the known range of *Cryptotis parva* approximately 80 miles south of the locality reported for Fisher County by Jones et al. (1991), about 90 miles west of the Brown County specimens (Pitts & Smolen 1988), and 150 miles north of the Del Rio record for Val Verde County (Bailey 1905). The record for Taylor County was unspecified to locality by Davis & Schmidly (1994) but it was later determined that the specimen was collected in Abilene (0.1 mi W intersection U.S. 83 and Ambler Street, 1700 ft elev.) on 1 November 1969 and was deposited in the Louisiana State University Museum of Zoology (LSUMZ 15588). Specimens reported herein are from approximately 70 miles southwest of that record. Although recent expansions of the range by this species to the north and west have been suggested, archaeological studies in Tom Green County have verified that the least shrew has potentially been a long time resident of this county. Scott & Creel (1990) reported a maxilla and humerus of *Cryptotis* from an excavation area with an estimated age dating from 1300 to 1650 A.D. Continuous occupation by the least shrew over the past few centuries in this region of Texas cannot be conclusively demonstrated from these archaeological data; however, the data do confirm prior occurrence of this shrew in the county.

Also of interest are two catalogued, but missing, specimens of the least shrew from adjoining counties. Simpson & Maxwell (1989) mentioned a specimen from Coke County which had been catalogued as *Cryptotis parva* (ASNHC 1044), but which could not be located. They suggested that its identity was suspect, based on the known range of the species. Similarly, a specimen from 3.5 mi NE of Eden, Concho County catalogued as *Cryptotis parva* in the Strecker Museum has subsequently been lost. Both of these specimens could well have been least shrews, based on the verification of this species occurring in west-central Texas. Unfortunately, because of the loss of the specimens, further field work will be required in these areas before the presence of this species can be substantiated in Coke and Concho counties.

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BOOK REVIEW

The Impact of Global Warming on Texas. A Report of the Task Force on Climate Change in Texas. Edited by Gerald North, Jurgen Schmandt and Judith Clarkson. University of Texas Press, 1995. First Edition, 242 pages. ISBN 0-292-75555-4 HB.

Do we need a comprehensive examination of the potential impacts of climate change on Texas? Yes, as this book shows, the size, geographical location, water resources and petroleum based economic sectors of Texas will make this examination necessary and fruitful. Although some of the scenarios may need to be revised according to the 1995 update from the Intergovernmental Panel on Climate Change, the book is a must for environmental policy making in the state. It would be great if the Task Force could disseminate future updates of scenarios and results via the network or a journal article.

After a delightfully simple and complete first chapter on global climate change, an overview chapter on Texas' climate provides the reader with an adequate background to understand current Texas climate patterns. Then, an analysis of emissions of greenhouse gases in Texas gives a perspective of the importance of the State as contributor to global warming. The following six chapters cover a wide range and fairly complete spectrum of potential impacts of global warming on Texas: water resources, estuaries, biodiversity of terrestrial landscapes, agriculture, urban areas and economic sectors. All these chapters are very well done and succeed at providing the scope of potential effects. The chapter on the economy introduces some discussion of policy alternatives to lead into the last chapter on policy options to address impacts of global warming on Texas. This last chapter emphasizes a discussion of water management and of coastal effects due to a sea level rise, which are obviously very important. However, it would have been nice if this chapter had examined all the various impacts discussed in the previous six chapters in order to look for possible policy alternatives.

This book is a must for environmental policy making in the state and will also serve as excellent supplementary reading material in Earth Science, Climatology, Water Resources and Global Change courses taught at Texas universities.

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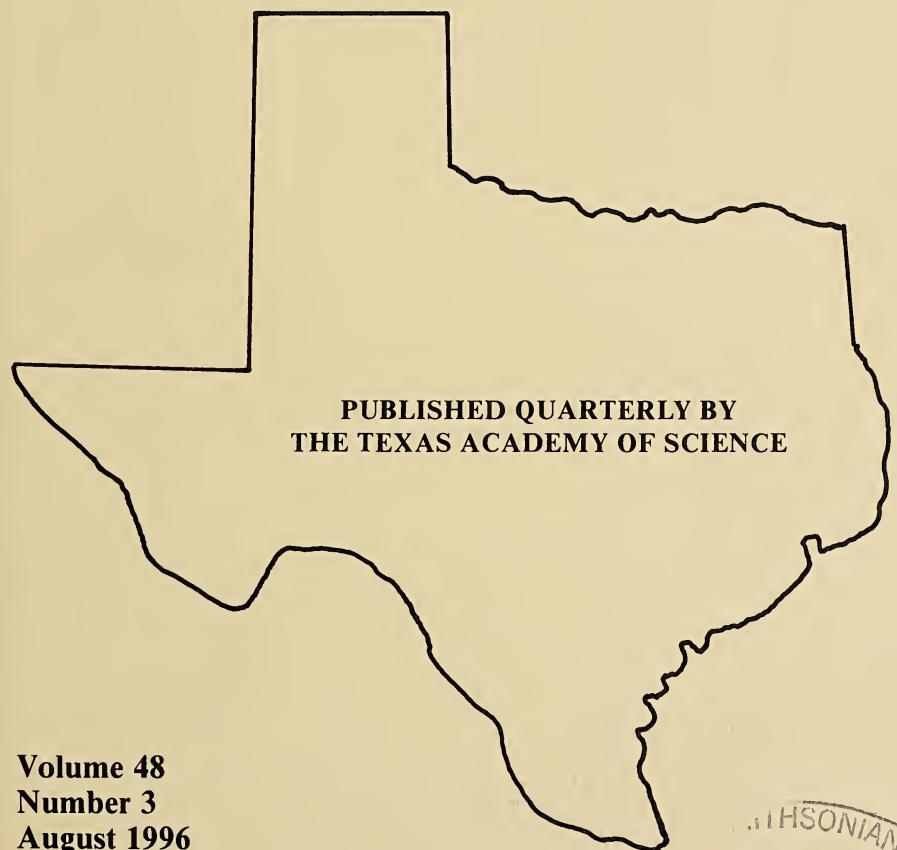
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A REEVALUATION OF POPULATIONS OF THE CORN SNAKE *ELAPHE GUTTATA* (REPTILIA: SERPENTES: COLUBRIDAE) IN TEXAS

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Abstract.—Three hundred thirty-seven preserved specimens of the corn snake *Elaphe guttata* from Texas, six from Arkansas, 51 from Louisiana and 20 from Missouri were examined and assigned to one of three subspecies. Based upon the number of dorsal body and tail blotches, the number of ventrals and subcaudals, the degree of ventral pigmentation and the presence or absence of paired subcaudal stripes, each specimen was assigned to *Elaphe guttata emoryi* (great plains rat snake), *E. guttata meahllmorum* (southwestern rat snake) or *E. guttata guttata* (corn snake). When collection localities for the Texas specimens were plotted on a map by subspecies, the resulting distribution of the three subspecies represents a departure from the previous ranges for these subspecies in the state. Eastern specimens are newly assigned to the subspecies *E. guttata guttata*, part of the central and all of the northwest specimens represent *E. guttata emoryi*, and *E. guttata meahllmorum* are restricted to southern Texas. A zone of intergradation exists between *E. guttata emoryi* and *E. guttata meahllmorum* along the southern part of the Edwards Plateau and the Rio Grande River basin from Val Verde to El Paso counties. A suspected contact between populations of *E. guttata emoryi* and *E. guttata guttata* occurs in Milam County, Texas.

An examination of Texas specimens of *Elaphe guttata* for number of dorsal body and tail blotches, number of ventrals and subcaudals, and degree of ventral pigmentation suggests several taxonomic scenarios. Thomas (1974), after detailed analysis of morphological traits, suggested that all Texas *E. guttata* belonged to the race *E. guttata emoryi*. Smith et al. (1994) analyzed similar characters and suggested that Texas *E. guttata* represented two races, *E. guttata emoryi* and a new subspecies *E. guttata meahllmorum*. In addition, Smith et al. (1994) extended the range of *E. guttata meahllmorum* through all of east-central Texas, and parts of central and northwestern Texas, with an isolated population in southern Missouri and Arkansas. The eastern Texas population was assigned to the race *E. guttata meahllmorum*, based upon its low body blotch counts and brownish, rather than reddish, coloration by which the authors distinguished it from *E. guttata guttata*.

The most important character upon which Smith et al. (1994) based their subspecies determination was the number of body blotches (≤ 44.5 for *E. guttata meahllmorum*, ≥ 45 for *E. guttata emoryi*), followed to

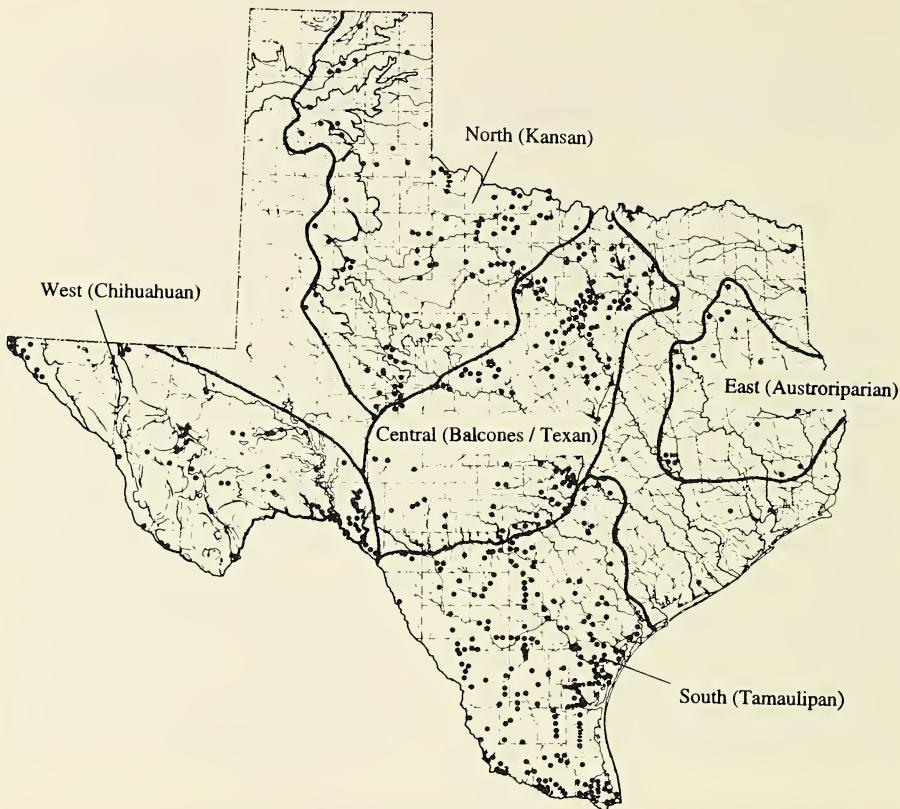


Figure 1. Distribution of *Elaphe guttata* in Texas, which has been subdivided into five ecophysiographic regions (after Blair 1949; Owen & Dixon 1989; Ward et al. 1994).

a lesser extent by number of tail blotches (< 18.5 in 75% of *E. guttata meahllmorum* examined). Less distinct differences were found between the two races in the number of ventrals and subcaudals, and in ventral pattern. The authors noted a reduction in ventral pigmentation in the majority of *E. guttata meahllmorum* examined, and an increased numbers of ventral scales. Although the authors noted some latitudinal clinal effects on number of body and tail blotches, they pointed out that 17% of the variation noted in the first character and 10% in the second character could not be explained by those effects. Differences in ventrals and subcaudals, although significantly different between the two races, were generally less than what could be attributed to clinal variation. The authors predicted that, for the clinal effects noted, physiographic and climatological forces, if analyzed by the methods of Owen & Dixon (1989) or Ward et al. (1994), would be found to be cor-

related with the phenotypic clinal variation observed in the two subspecies.

The present study was undertaken in an effort to clarify the distribution of these races in Texas, where numerous instances of sympatry between *E. guttata emoryi* and *E. guttata meahllmorum* were found by Smith et al. (1994), when subspecies determination was based primarily upon the number of body blotches. A further goal of the present study was the examination of the characters of the eastern Texas population, which appeared to be geographically disjunct from the other Texas races, to determine its proper assignment.

MATERIALS AND METHODS

Three hundred thirty-seven specimens of *Elaphe guttata* from Texas, six from Arkansas, 51 from Louisiana and 20 from Missouri were examined. The Texas specimens (Fig. 1) represented localities from nearly all geographic areas of the state where the species has been collected (Dixon 1987). One-hundred five of the specimens examined were cataloged in the Texas Cooperative Wildlife Collection (TCWC), and most of the remainder were specimens from other museums examined by author Thomas during the course of his MS thesis research in the early 1970's (Thomas 1974).

Standard scutellation methods were used in examining the specimens, following sex determination. Ventrals were counted as proposed by Dowling (1951). Body blotches were counted according to the methods of Thomas (1974) and Smith et al. (1994), so as to ensure comparability of results. Tail blotches and subcaudals were not counted on specimens with blunted or badly damaged tails; body blotches were not counted on specimens which were badly faded, or for which body blotches were extensively fused. Specimens were examined for the presence or absence of paired subcaudal stripes.

The degree of ventral pigmentation was determined for the 105 TCWC specimens by visual examination and sorting of the specimens into three groups, i.e., light, intermediate, or heavy ventral pigmentation. From each of the three groups, a subsample of ten individuals was drawn randomly. For each individual, the number of immaculate ventral scales was counted, according to the method of Thomas (1974) and that number was divided by the total number of ventral scales. This ratio, which allowed comparability of TCWC specimens to those examined in the Thomas (1974) study, provided a

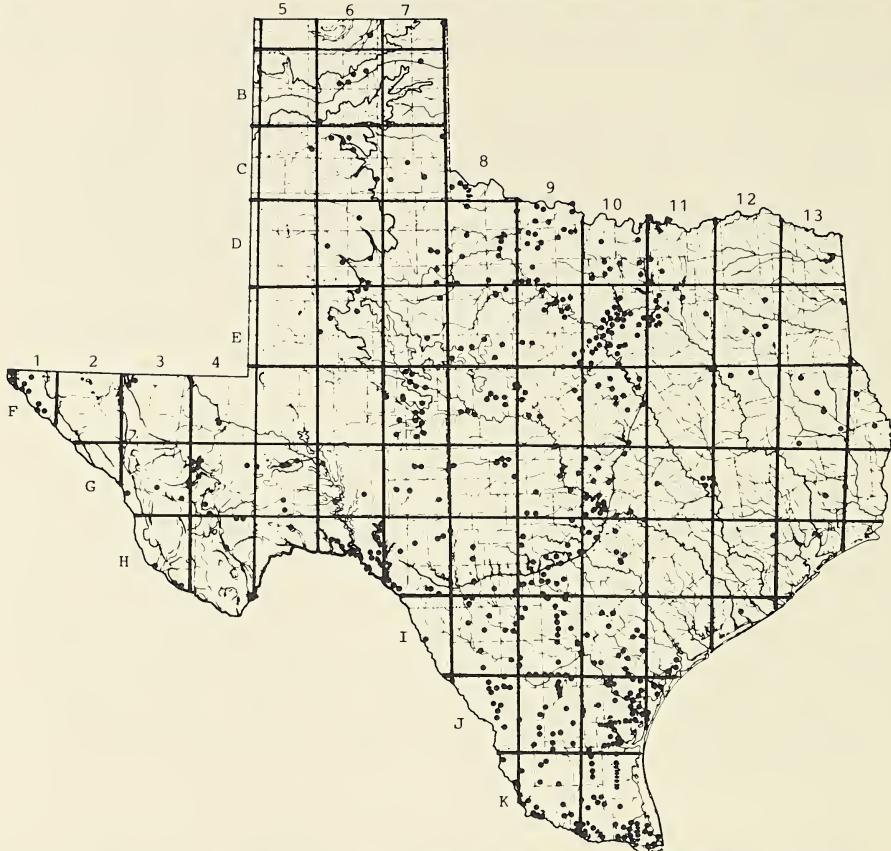


Figure 2. Distribution of *Elaphe guttata* in Texas with the state subdivided into one-degree square quadrats, north to south (B-K) and west to east (1-13). The two specimens east of quadrat 13-F were included with 13-F. The single individual in quadrat 12-H (Houston) is probably an escaped pet, and was not included in calculations. The single individual in quadrat 12-I was not available for examination.

pigmentation index for each individual. Mean pigmentation index was calculated for each subsample (light, intermediate and heavy), and that value, along with two standard deviations on either side of the mean comprised the range of indices for the three ventral pigmentation categories. Using this method, each individual in this study was assigned to a category of either light ($\bar{X} = 0.59$, $SD = 0.07$), intermediate ($\bar{X} = 0.38$, $SD = 0.04$), or heavy pigmentation ($\bar{X} = 0.23$, $SD = 0.38$). Without regard to subspecies assignment as originally recorded in the museum's catalog, each snake's collection site was plotted (Figs. 1 and 2) on a Texas map. Means of continuously distributed characters were compared (1) among samples of individuals within one-degree square quadrats (Fig. 2) on the map; (2) among samples

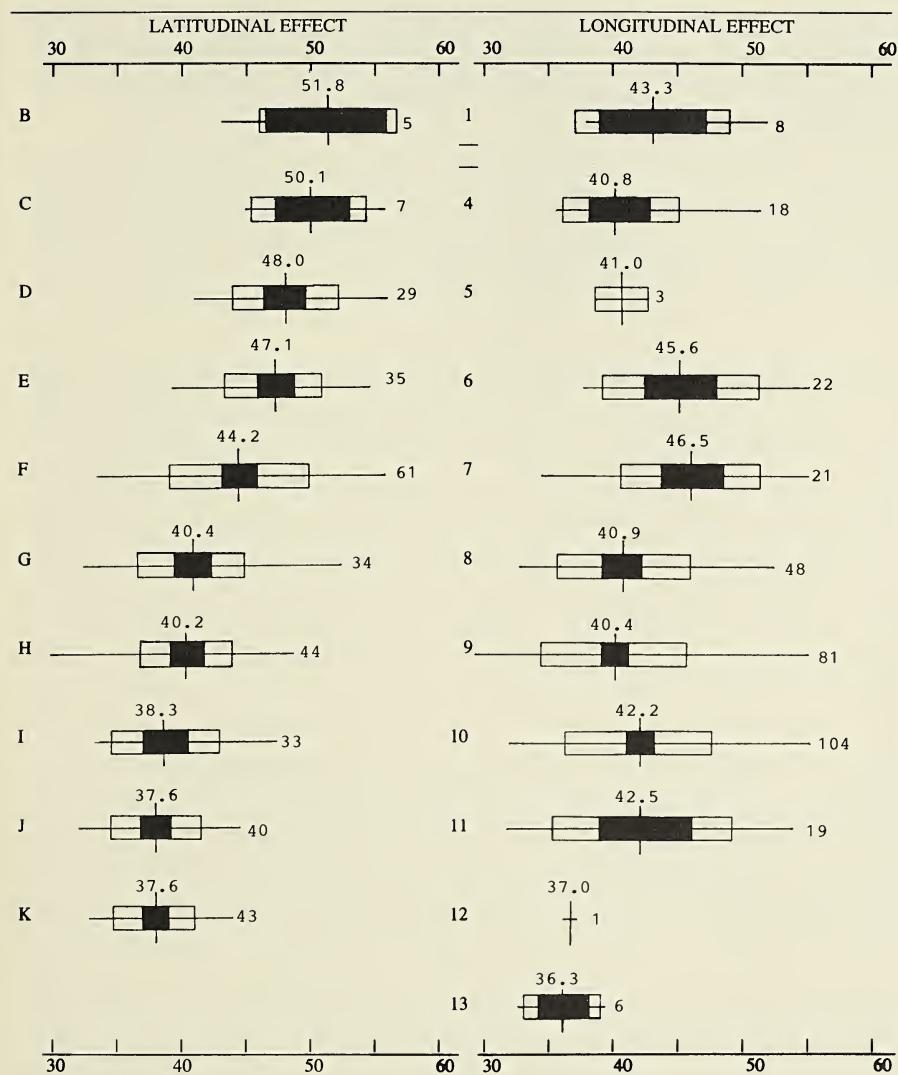


Figure 3. Mean body blotch counts (sexes combined) for *Elaphe guttata* in Texas. Samples B-K represent summed one-degree increments from North (B) to South (K) Texas. Samples 1-13 represent summed one-degree increments from West (1) to East (13) Texas. Black rectangles represent two standard errors, and white rectangles represent one standard deviation, on either side of the mean. Sample ranges are indicated by horizontal lines; means by vertical lines. Sample sizes are listed to the right of each sample. Samples 2 and 3 contained no specimens.

summed latitudinally by one-degree increments (11 degrees) from north to south; (3) among samples summed longitudinally by one-degree increments (13 degrees) from east to west; and (4) among samples

grouped by ecophysiographic regions based on the criteria of Blair (1949), Owen & Dixon (1989), and Ward et al. (1994), as shown in Figure 1. Statistical analyses were performed using SAS (SAS Institute, Inc. 1985).

Material examined.—Texas (337 specimens), Arkansas (six specimens), Missouri (20 specimens), Louisiana (51 specimens). A complete list of specimens examined, by museum number and locality, may be obtained from the authors upon request.

RESULTS

Mean number of body blotches was not significantly different between the sexes. When mean body blotch data for the sexes were pooled, summed and plotted by one-degree increments latitudinally (Fig. 3) a general north-south cline was seen in this character, with significant differences in adjacent samples seen only between samples E and F, and between F and G (Tukey's HSD with Confidence Limits, $P < 0.05$). Lower mean body blotch counts were seen toward the south and southwest portions of the state. Analyzed longitudinally by one-degree increments (Fig. 3), a slight directional cline was found from west to east up through sample seven, at which point body blotch counts decreased significantly (Tukey's HSD with Confidence Limits, $P < 0.05$), continuing into samples eight and nine. Otherwise, no significant difference between adjacent samples was found longitudinally, except in eastern Texas (samples 12 and 13), which had significantly lower (≤ 37) mean body blotch counts. All specimens but two examined from southern Texas below the Edwards Plateau had a body blotch count of 44 or lower, and another group of snakes with low (≤ 41) body blotch counts occurred near Persimmon Gap, north of the Big Bend area. Sympatric localities were found for snakes with low (≤ 44.5) and high (≥ 45) body blotch counts in western, central and north central Texas, with body blotch counts as disparate as 40 and 54 occurring within the same area of Bosque County (see map in Smith et al. 1994).

Overall, mean tail blotch counts were higher for males than females ($t = 5.50$, $df = 301$, $P < 0.01$), but no single directional cline was seen in this character for either sex when summarized latitudinally by one-degree increments. No significant differences in means were found between adjacent samples for either sex. When analyzed longitudinally, this character did not exhibit directional clinal variation, nor did adjacent samples differ.

Light ventral pigmentation was most often found in the southern Texas samples, although snakes with light, intermediate, and heavily

Table 1. The mean scale and blotch counts of Texas *Elaphe guttata* by ecophysiographic region and sex. Sample sizes are shown in parentheses.

	Dorsal Blotches		Tail Blotches		Ventrals		Caudals	
	Males	Females	Males	Females	Males	Females	Males	Females
NW Texas	48.4(29)	47.4(25)	20.1(27)	18.4(22)	212.7(29)	218.5(25)	69.4(29)	64.8(24)
Central Texas	45.6(55)	44.7(30)	18.4(54)	16.8(29)	212.7(54)	218.2(29)	69.2(54)	64.2(28)
West Texas	42.3(23)	39.8(16)	17.7(22)	15.1(14)	211.2(17)	213.7(14)	73.8(16)	65.0(13)
South Texas	38.5(89)	37.1(45)	17.8(80)	15.6(39)	218.5(87)	224.5(46)	76.6(81)	71.4(44)
East Texas	36.7(14)	38.3(4)	14.3(12)	13.8(4)	213.3(12)	224.5(4)	66.8(10)	67.0(4)

pigmented venters were observed from almost all areas of the state. In some one-degree-square quadrats, snakes with all three pigmentation scores were seen. Of 46 heavily pigmented snakes examined from the TCWC, 58.7% had dorsal body blotch counts below 44.5, compared to 58.1% of intermediate-pigmented snakes, and 100% of light-ventered snakes. The majority of the snakes examined from far eastern Texas had heavily pigmented venters, in conjunction with a dorsal body blotch count of 41 or less.

Paired subcaudal stripes occurred on light, intermediate, and dark-ventered snakes alike, although dark ventered snakes were most likely to possess subcaudal stripes (82.6%, as opposed to 41.9% for intermediate-ventered snakes, and 32.1% for individuals with light venters). In eastern Texas, 90.9% of specimens examined possessed subcaudal stripes.

It quickly became apparent that analyzing the characters simply by comparing the means of samples summed by increments latitudinally and longitudinally tended to mask population variation within each one-degree sample. For example, the mean body blotch count of longitudinal samples eight and nine included numerous higher-blotch-count snakes in the northern part of the state, which were counterbalanced by the preponderance of very low-blotch-count specimens from southern Texas.

When the data were grouped by the less arbitrary and more environmental parameter-based category of ecophysiographic region (Fig. 1), a much clearer separation of some of the character states emerged for the three races of *E. guttata*. Body blotches, which did not differ between the sexes, varied significantly (Table 1) among the ecophysiographic regions ($f = 80.8$, $df = 4, 325$, $P < 0.01$), but this character

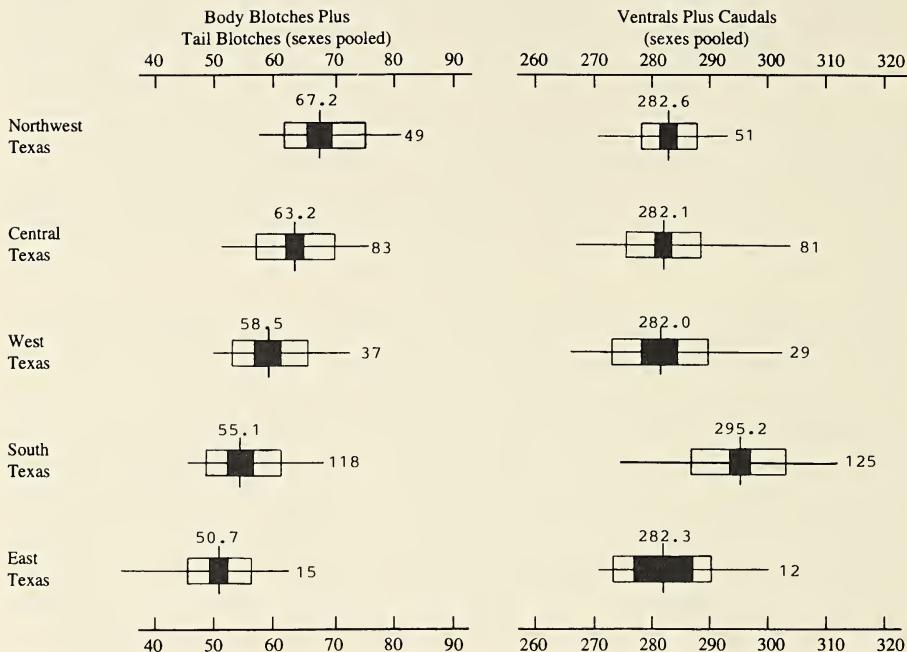


Figure 4. On the left, mean body blotches plus tail blotches (with sexes pooled) for samples of *Elaphe guttata* from five ecophysiographic regions of Texas (after Blair 1949; Owen & Dixon 1989; Ward et al. 1994). To the right, ventrals plus subcaudals (with sexes pooled) for the same samples. Samples were arranged on the chart in descending order of mean body blotches plus tail blotches. Horizontal lines denote ranges, vertical lines denote means. Black rectangles represent two standard errors and white rectangles represent one standard deviation, on either side of the mean.

alone could not be used to separate *E. guttata emoryi* from *E. guttata meahllmorum*, as the character showed a general north-south cline of decreasing blotch counts (Fig. 3), with North Texas having the highest mean body blotch counts, followed by Central Texas, West Texas, South Texas, and East Texas. Tail blotch counts decreased roughly north to south in the same order, for both sexes, with East Texas again having the lowest counts.

After approaching the problem in several ways, two new characters were developed and calculated for each individual, (1) the sum of ventrals plus subcaudals and (2) the sum of body blotches plus tail blotches. Although number of ventrals differed between the sexes ($t = 7.64$, $df = 314$, $P < 0.001$), as did number of subcaudals ($t = 7.92$, $df = 297$, $P < 0.0001$), when ventrals and subcaudals were summed

for each individual, and compared by sex within an ecophysiographic region, the counts did not differ significantly. For this new character, therefore, the data for the sexes could be pooled, yielding larger sample sizes. Likewise, although the number of body blotches did not differ between the sexes ($t = 0.73$, $df = 328$, $P = 0.465$), the number of tail blotches were significantly different ($t = 5.50$, $df = 301$, $P < 0.0001$), with males having a mean of 1.8 more blotches than females. When the sum of body blotches plus tail blotches was calculated for each individual, however, and the means were compared between the sexes within each ecophysiographic region, no significant differences were found, thus allowing the pooling of the sexes for this character as well. When these two new characters were analyzed by ecophysiographic region (Fig. 4), single classification MANOVA showed significant variation in this character among ecophysiographic regions ($f = 13.0$, $df = 169$, $P, 0.0001$), with snakes from South and East Texas having lower body-plus-tail blotches than those from West Texas (Tukey's HSD, $P < 0.05$). Body blotches plus tail blotches were significantly higher in North Texas than in Central Texas (Tukey's HSD, $P < 0.05$). Ventrals plus subcaudals did not differ among the samples from West, North, Central, or East Texas ($f = 0.08$, $df = 172$, $P = 0.971$) as shown in Figure 4. The mean for the four regions varied by less than one scale. However, the mean for this character was significantly higher (by more than 10 scales) in South Texas (Tukey's HSD, $P < 0.05$).

Table 2 shows the relationship of mean scale and blotch counts for all Texas *E. guttata* among the five ecophysiographic regions. Using Tukey's Studentized Range Test with Confidence Limits (alpha = 0.05), regions that did not significantly differ for a character were grouped. Snakes in South Texas and East Texas, both previously proposed to be *E. guttata meahllmorum* (cf. Smith et al. 1994) could not be separated on the basis of body blotch counts, however, the two regions differed significantly in the sum of body blotches plus tail blotches (higher in South Texas), and, most dramatically, in the sum of ventrals plus subcaudals (higher in South Texas). All five ecophysiographic regions differed from each other (Table 2) in the sum of body blotches plus tail blotches, with a general north-south cline for the character for North, Central, West and South Texas. East Texas, not included in the north-south cline, was lower than any other region. In the character of ventrals plus subcaudals, North, Central, West, and East Texas could not be separated from each other. South Texas, however, stood apart from the other four regions.

Table 2. Relationships of characters of *Elaphe guttata* from Texas when analyzed by single classification MANOVA among ecophysiological regions, arranged in descending order. Non-significant subsets (Tukey's Studentized Range Test with Confidence Limits, alpha = 0.05) are grouped by vertical lines.

Character	n	Min	Max	SD	Mean	Tukey's
Body Blotches (Sexes Pooled)						
Northwest	54	41	56	4.2	47.9	
Central	85	35	56	4.8	45.3	
West	40	36	53	4.3	41.5	
South	134	29	48	3.5	38.0	
East	17	32	41	2.9	36.8	
Tail Blotches (Females)						
Northwest	22	14	23	3.0	18.4	
Central	29	12	20	2.1	16.8	
West	14	13	19	1.4	15.1	
South	39	10	20	2.2	15.6	
East	4	12	16	1.7	13.8	
Tail Blotches (Males)						
Northwest	25	14	26	2.9	20.1	
Central	54	14	23	2.2	18.4	
West	22	12	23	2.6	17.7	
South	80	12	23	2.4	17.8	
East	12	11	18	2.2	14.2	
Ventrals (Females)						
South	46	213	233	5.0	224.5	
East	4	212	234	9.2	224.5	
Northwest	25	211	227	4.0	218.5	
Central	29	211	224	3.4	218.2	
West	14	207	222	4.7	213.7	
Ventrals (Males)						
South	87	205	232	5.9	218.4	
East	12	206	219	3.6	213.3	
Northwest	29	206	225	4.1	212.7	
Central	54	202	230	5.0	212.7	
West	17	202	222	5.4	211.2	
Caudals (Females)						
South	44	55	83	5.8	71.4	
East	4	65	69	2.0	67.0	
West	13	55	72	4.6	65.0	
Northwest	24	61	72	2.9	64.8	
Central	28	50	69	3.9	64.2	
Caudals (Males)						
South	81	61	86	5.1	76.6	
West	16	68	81	3.7	73.8	
Northwest	29	57	76	4.4	69.4	
Central	54	58	82	3.6	69.2	
East	9	61	74	4.3	66.5	
Body Blotches Plus Tail Blotches (Sexes Pooled)						
Northwest	49	57	81	6.6	67.2	
Central	83	51	76	6.2	63.2	
West	37	50	73	6.1	58.5	
South	113	39	67	5.0	55.1	
East	15	44	59	4.1	50.7	
Ventrals Plus Caudals (Sexes Pooled)						
South	125	275	312	7.9	295.2	
Northwest	51	271	293	5.2	282.6	
East	12	272	299	8.1	282.3	
Central	81	268	304	6.1	282.1	
West	29	267	303	8.1	282.0	

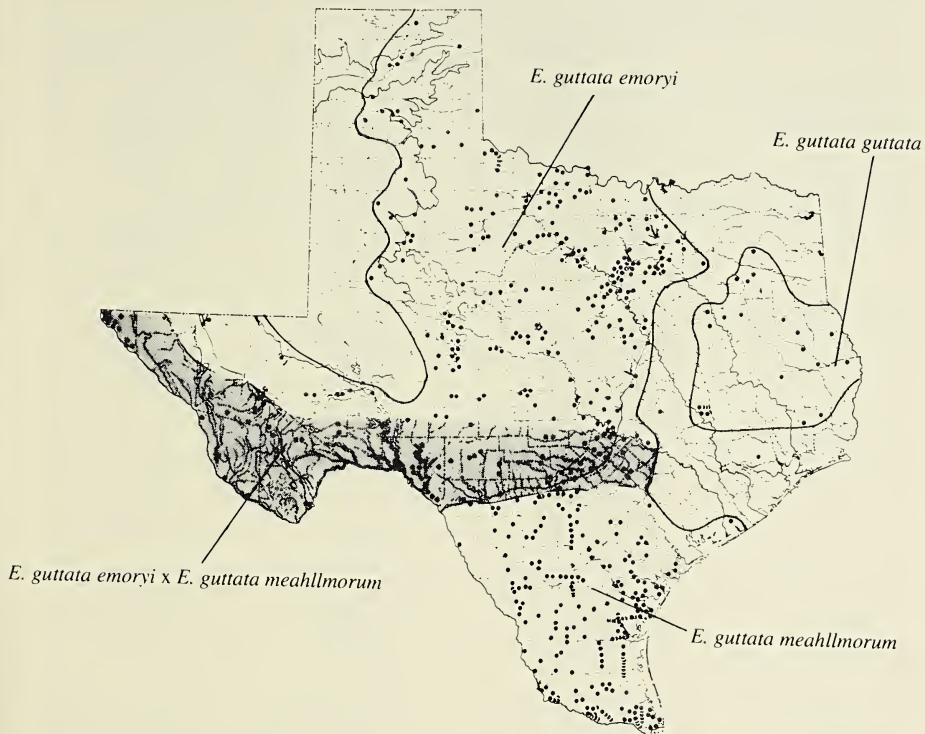


Figure 5. Distribution of the three races of *Elaphe guttata* in Texas. Shaded region denotes zone of intergradation between *E. guttata emoryi* and *E. guttata meahllmorum*.

DISCUSSION

Based upon the blotch counts, relative degree of ventral pigmentation, and the presence or absence of subcaudal stripes in the samples from the five ecophysiographic regions of Texas, it is possible to define the continuously distributed characters (Table 3) and distribution of the three races of *E. guttata* in Texas (Figure 5), with *E. guttata guttata* in eastern Texas, *E. guttata emoryi* in Central and North Texas, and *E. guttata meahllmorum* in South Texas. Based upon examination of the character states of individuals collected from localities where the races are in contact, it is suggested that a intergradation zone exists between *E. guttata meahllmorum* and *E. guttata emoryi* along the southern part of the Edwards Plateau, and West Texas to the El Paso region. The width of the intergradation zone is about 100 miles. This zone was approximated by selecting large samples of individuals occurring in the critical area, and scoring each individual within these samples as one

Table 3. Distribution of characters of *Elaphe guttata emoryi*, *Elaphe guttata meahllmorum* and *Elaphe guttata guttata* from Texas.

Character	<i>E. g. emoryi</i>	<i>E. g. meahllmorum</i>	<i>E. g. guttata</i>
Body Blotches (Male)			
N (Range) \bar{X}	88 (38-56) 46.6	107 (31-53) 39.0	14 (32-42) 36.7
< 45	34.0%	94.4%	100.0%
< 35.5	0.0%	14.9%	35.7%
Body Blotches (Female)			
N (Range) \bar{X}	58 (35-56) 45.8	58 (29-52) 37.7	4 (36-40) 38.3
< 45	34.4%	96.6%	100.0%
< 35	0.0%	17.2%	0.0%
Tail Blotches (Male)			
N (Range) \bar{X}	85 (14-26) 18.9	97 (12-23) 17.8	12 (11-18) 14.3
< 18.5	48.2%	62.9%	100.0%
< 16.0	8.2%	15.5%	66.7%
< 15.0	4.7%	10.3%	58.3%
Tail Blotches (Female)			
N (Range) \bar{X}	54 (12-23) 17.4	51 (10-19) 15.5	4 (12-16) 13.8
< 18.5	61.1%	92.2%	100.0%
< 16.0	27.8%	51.0%	75.0%
< 15.0	11.1%	27.5%	25.0%
Ventrals (Male)			
N (Range) \bar{X}	85 (202-230) 212.9	101 (202-232) 217.2	12 (206-219) 213.0
< 213	50.6%	77.9%	41.7%
< 215	95.3%	35.6%	58.3%
< 218	100.0%	49.5%	91.7%
Ventrals (Female)			
N (Range) \bar{X}	56 (211-227) 218.4	57 (207-233) 222.0	4 (212-234) 224.5
< 220	59.0%	31.6%	25.0%
< 222	82.1%	45.6%	25.0%
< 225	94.6%	57.9%	25.0%
Subcaudals (Male)			
N (Range) \bar{X}	83 (57-82) 69.3	94 (61-86) 76.3	10 (61-74) 66.8
< 72	81.9%	17.0%	90.0%
Subcaudals (Female)			
N (Range) \bar{X}	54 (50-72) 64.6	55 (55-83) 69.9	3 (65-69) 67.0
< 72	98.2%	67.3%	100.0%
Body blotches plus tail blotches (sexes pooled)			
N (Range) \bar{X}	49 (57-81) 67.2	118 (39-67) 55.1	15 (44-59) 50.7
< 50	0.0%	12.7%	33.3%
< 55	0.0%	45.8%	86.7%
< 60	6.1%	41.5%	100.0%
Ventrals plus subcaudals (sexes pooled)			
N (Range) \bar{X}	51 (271-293) 282.6	125 (275-312) 295.2	12 (272-299) 282.3
< 280	25.5%	1.6%	41.7%
< 285	68.6%	10.4%	66.7%
< 290	86.3%	22.4%	83.3%
Ventral pigmentation	52 (sexes pooled)	129 (sexes pooled)	16 (sexes pooled)
Heavy	42.3%	10.9%	81.3%
Intermediate	46.2%	28.6%	18.7%
Light	11.5%	60.5%	0.0%
Subcaudal Stripes	28 (sexes pooled)	40 (sexes pooled)	11 (sexes pooled)
Present	82.1%	27.5%	90.9%
Absent	17.9%	72.5%	9.1%

race or the other, or as an intergrade, on the basis of degree of ventral pigmentation, number of dorsal blotches, number of tail blotches, total ventrals (ventrals plus subcaudals), and presence or absence of a subcaudal stripe (see Table 3). If 75% or more of the sample proved to be *E. guttata emoryi* or *E. guttata meahllmorum*, then the entire sample was included within the range of one of these races. If less than 75% of the sample could be identified to any one race, or if more than 25% were unidentifiable to race (intergrades), then the entire sample was placed within the intergradation zone.

The present study suggests that the southeastern population of *Elaphe guttata* in Texas is *E. guttata guttata*, based upon low body and tail blotch counts in conjunction with the presence of heavy ventral pigmentation with subcaudal stripes. This brown-phase population is a westward extension of eastern *E. guttata guttata* west of the Mississippi River. The Louisiana, Arkansas and southern Missouri samples examined by Smith et al. (1994) and Thomas (1974) are likely members of that race as well. No contact was found between this eastern Texas race and any other race in Texas. The two Milam County individuals not included in the East Texas sample may represent *E. guttata guttata*. This is based on color pattern and number of body blotches. This remains uncertain due to the fact that complete patterns were not observable on one of the specimens.

Twenth-six specimens of *E. guttata* were examined from the Austro-riparian zone of eastern Texas and Louisiana west of the Mississippi River. As discussed in Conzelmann & Thomas (1971), Hahn et al. (1972) and Raymond & Hardy (1983), there is considerable color variation in this zone. Raymond & Hardy (1983) believed this variability to suggest secondary intergradation. In general, the specimens of *E. guttata* from this defined area are dark specimens approaching *E. guttata guttata* in pattern (shape of dorsal blotches, ventral pattern of body and tail), but lacking the characteristic yellow and red colors. Instead, these snakes typically have a grayish ground color with rich reddish-brown blotches. Hahn et al.'s (1972) decision to assign a specimen from Natchitoches Parish, Louisiana, to *E. guttata emoryi* was based on the grayish ground pattern. An examination of this specimen revealed that it conforms to all other specimens from that region. The only specimens of "typical" *E. guttata guttata* west of the Mississippi River are from the Louisiana parishes of Iberia, Point Coupee and West Baton Rouge (Raymond & Hardy 1983; observations this study). The ground color of the Texas population is tan, grayish-tan or orangish-tan, with brown

or reddish-brown body blotches. Body and tail blotches are few in number (Table 3), the dark subcaudal stripes are bold, and the black ventral markings are large, bold, and numerous. Texas specimens of *E. guttata guttata* west or south of Brazos/Grimes counties, nor more than 20 miles west of the natural pine-oak stands of East Texas (Fig. 1) were not verified.

As for the remaining populations of *E. guttata* in Texas, the variation observed in dorsal body and tail blotches (higher in northern Texas, lower in southern and western Texas) may reflect a phenotypic response to a temperature gradient (Owen & Dixon 1989) from north to south. The low to high body blotch count cline from Central to northwestern Texas suggests variation reflecting a humidity gradient (Owen & Dixon 1989), but may also be influenced in part by temperature. Likewise, the low to high body blotch cline from western to central Texas may be related to the rainfall/humidity gradient proposed by Owen & Dixon (1989), but the significant drop in body blotch count at samples eight, nine and 10, and between latitudinal samples F and G, probably reflect the inclusion of the large number of low blotch count individuals from southern, or western and eastern Texas, respectively. Whatever the case, analysis of all character states suggests that incipient speciation may be in progress.

Although body blotch count was the primary character utilized by Smith et al. (1994) to separate *E. guttata meahllmorum* from *E. guttata emoryi*, for Texas it is suggested that clinal variation is more significant than they believed it to be, and that it would be difficult to separate the subspecies on body blotches alone. Although the number of body blotches are lower in southern Texas, a general range of 12 body blotches occurs in any given southern Texas sample, and for any sample of adequate size throughout Texas, suggesting that clinal variation appears to be the rule rather than the exception for all Texas samples, regardless of how they are arranged. However, in combination with other characters, the number of body blotches may help identify a specimen.

A more reliable set of characters are the number of ventrals plus subcaudals (significantly higher in *E. guttata meahllmorum*), and the relatively light ventral pigmentation in *E. guttata meahllmorum*. Samples examined during this study suggest that a step cline exists in these characters between the edge of the Edwards Plateau (*E. guttata emoryi*) and the Tamaulipan Biotic Province (*E. guttata meahllmorum*) (Fig. 4).

It was first thought that *E. guttata meahllmorum* merely represented the end of a cline, and was an integral part of the southern end of the distribution of *E. guttata emoryi*. This assumption was based on the number of dorsal body blotches and followed Smith et al. (1994). This study did not *a priori* separate specimens by their number of body blotches before analyzing their other characters. This attempt to increase objectivity led to a validation of the new race *E. guttata meahllmorum* on the basis of a combination of characters. The most significant of these is the sum of ventrals and subcaudals, degree of ventral pigmentation and the number of body blotches. The same criteria also facilitated the determination of the presence of *E. guttata guttata* in eastern Texas.

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**NOTES ON THE BIOLOGY OF THE SLIDER,
TRACHEMYS SCRIPTA ELEGANS (REPTILIA: EMYDIDAE),
INHABITING MAN-MADE CATTLE PONDS IN WEST TEXAS**

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Abstract.—*Trachemys scripta elegans* (Wied-Neuwied) inhabiting two man-made cattle ponds (0.23 and 0.18 ha) were studied in West Texas during a two year period. Adult females appeared to outnumber adult males. Males were less likely to be recaptured than females. Forty-six percent of the turtles from Sims Pond were captured only once whereas 61% from Quahadi Pond were captured once. The highest number of captures of an individual was eight. Cloacal extension past carapace margin, claw and tail lengths relative to carapace length were sexually dimorphic and females obtained larger size than males. As determined by radiography, the mean number of eggs was eight. Density estimates for Sims Pond were 513 and 247 turtles per ha in 1988 and 1889, respectively; for Quahadi Pond they were 983 and 333. Biomass estimates for Sims Pond were 462 and 374 kg/ha per year; for Quahadi Pond they were 304 and 194 kg/ha per year.

Trachemys scripta is a widely distributed aquatic emydine turtle inhabiting a variety of habitats from large rivers to small artificial ponds (Gibbons 1990). This turtle reaches its western distribution limits in western Texas and eastern New Mexico (Ernst et al. 1994). Although aquatic, individuals traverse long distances between ponds (Cagle 1939) and in West Texas, animals are occasionally found considerable distances from surface water. On the Llano Estacado in West Texas and eastern New Mexico, *T. scripta* is virtually absent except along entrenchment canyons. This turtle is, however, common up to the escarpments that outline the Llano Estacado.

The Llano Estacado was once an immense grassland. Directly beneath the relatively thin top soil is a thick (up to 20 feet) layer of caliche that is resistant to erosion, causing the Llano Estacado to be one of the largest mesas ($88,060 \text{ km}^2$) in the world (Walker 1978). Its surface is pocked by numerous (12,000) ephemeral ponds called playas and because of the lack of geological relief, nearly 90% of all rainfall striking this plain is captured on the surface. To the east, south, and west the Red, Brazos, Colorado and Pecos rivers have etched into the Llano Estacado leaving escarpments, some as high as 275 m. The area immediately south and east of the Llano Estacado is composed of exposed Triassic Red beds sustaining mesas of varying size (Walker 1978). Erosional troughs in this landscape occasionally are dammed to

A**B**

Figure 1. A. Sims Pond. The shortest distance across the pond at this water depth is 25 meters. B. Quahadi Pond with a turtle trap in the foreground. Note the lack of emergent vegetation in both ponds.

trap rain and water that seeps from the few springs emerging from the escarpments. Many of these basins are about 0.2 ha in surface area and

for much of the year they represent the only source of standing water for wildlife.

In 1988 two ranch ponds were selected near Post, Texas, in which to study *T. scripta*. Ponds were selected because turtles were observed at both sites. The ponds were of equal size, approximately 1.6 km distant, and both basins had retained water for the previous ten years. In addition, the ponds were distant from other surface water, minimizing migration as a mitigating factor impacting short-term population demographics. The initial goal of this study was to establish a data base of known (marked) animals that could be captured at differing times (seasonally) to yield information on individual and population characteristics. Baseline data accumulated between August 1988 and September 1990 provide additional information relative to the natural history of this species in what can be construed to be an environmentally inhospitable habitat.

METHODS AND MATERIALS

Description of ponds.—The Sims and Quahadi ponds (Fig. 1) are man-made impoundments approximately 11 km WSW of Post, Garza County, Texas. Earthen dams were built across natural drainages that funneled runoff water into the upper Brazos River system. Basin depths were enhanced by soil removal during construction of these dams. During this study, maximum water depth in each pond was about 2.5 m. Sims Pond had a surface area of approximately 0.23 ha and Quahadi Pond, 0.18 ha. Mean rainfall in the area is 55 cm annually with most precipitation occurring during spring and summer thunder-storms.

The area surrounding the ponds is a highly eroded mesquite grassland, grazed by cattle which use the ponds as water sources. Soil was primarily Triassic red clay, formed as the result of a large distributary (Walker 1978). Overburden was eroded away, leaving a series of mostly small mesas capped with sandstone, caliche or Cretaceous marine deposits. Dominant aquatic plants were *Potomogeton* sp. and *Chara haitensis*. There was no emergent aquatic vegetation. Large-mouth bass (*Micropterus salmoides*), bullfrogs (*Rana catesbeiana*) and cricket frogs (*Acris crepitans*) were present at both ponds. *Rana blairi* was observed infrequently at Sims Pond.

The primary channel draining into Sims Pond extended toward Quahadi Pond, which was approximately 1.6 km west. Although a low

ridge separated the two ponds, their drainages met approximately 3 km SE. Each pond was about 11 km distant from the confluence of their shared drainages with the North Fork of the Brazos River. The nearest stock ponds were 6 and 8 km from the study ponds. Although the North Fork of the Brazos River was only 1.2 km (direct line) from Quahadi Pond, the intervening terrain is greatly dissected and flow in the river is intermittent and brief.

Capture and marking of turtles.—Attempts to capture turtles with 100 foot bag-seines and trammel nets were unsuccessful. Most turtles were captured in wire-mesh traps baited with either chicken parts, sardines, tripe, fresh fish or a combination. The majority of bait was placed in a sealed plastic porous container suspended from the center top of the trap. When available, a freshly killed fish was suspended in the center of the trap. Five to eight traps were set and baited in each pond. Generally traps were set in late afternoon and checked periodically into the night then left until the following morning. There were 19 trips (15 August 1988 - 15 September 1990) to Sims Pond and 15 trips (10 September 1988 - 15 September 1990) to Quahadi Pond to capture turtles.

Each turtle was marked by drilling a hole or scribing a "V"-shaped notch in a peripheral lamella and underlying bone (Cagle 1939). In addition, animals from Sims Pond were drilled through the lateral aspect of the xiphiplastron to indicate initial capture site.

Turtles were weighed with a hand-held Pesola scale and the following measurements taken: carapace length as a straight line distance from the anterior tip of the cervical to the tip of the most posterior marginal lamellae; carapace width at mid-bridge; plastron length as a straight line; claw length as the straight line length of the second right forelimb digit (the left side was used if the right side was damaged); cloacal extension as the distance between the distal end of the plastron to the proximal lip of the cloaca; tail length as the distance from the distal end of the cloaca to the tip of the tail. Sex was determined by forelimb claw length, by observing whether the cloaca extended past the carapace when the tail was extended, or by tail length.

Biomass was calculated as kg/ha. Initial capture mass was used to calculate biomass for turtles known to be present in the two ponds in 1988 or 1989. Known biomass is an under-estimate of total biomass. Unlike most other studies on turtles (i.e. Iverson 1982 and Congdon & Gibbons 1989) turtle populations at Sims and Quahadi ponds were

monospecific because only two individuals of one other species, *Kinosternon flavescens*, were found at one of the ponds over the two year period.

Differences between males and females relative to the number of times captured were analyzed using chi-square test (Sokal & Rohlf 1969). This test was also used to test for differences in sex ratios. The Bailey modification of the Peterson Index (Donnelly & Guyer 1994) was used to estimate population size at Sims Pond. The first and second days capture-recapture values were used in the calculation. Standard error of the estimate was calculated by the Bailey method (Donnelly & Guyer 1994). An estimate of population size was not made for Quahadi Pond because the recaptures for day two was zero.

Reproduction.—Gibbons & Greene (1979) first demonstrated that radiography was an acceptable, non-invasive method of ascertaining egg number and size in turtles. Twenty adult females (carapace length 170 - 250 mm) were x-rayed on 27 May and 31 May 1989 using equipment and methods of Judd & Rose (1989). Serial collection of individual females proved fruitless and x-raying was discontinued because of the distance between the ponds and equipment and the impracticality of returning turtles to the ponds in a timely manner.

RESULTS

Mortality.—Two male turtles marked on day one in Sims Pond were found dead on land, apparently killed by raccoons (*Procyon lotor*). One was found on the 11th capture day, the other on the 14th. One was known to be alive on the fourth capture day, the other on the eleventh. An unmarked adult female was found dead near Sims Pond and two intact juveniles were found dead in the water at Sims Pond. No turtles from Quahadi Pond were known to have died during the study.

Sex ratios.—A total of 276 turtles was captured (176 from Sims Pond and 100 from Quahadi Pond). There were 85 males, 149 females and 39 juveniles. The sex ratios (36.3 % males, 63.7% females) did not vary between ponds. The difference between females and males was significant ($X^2 = 18.8$; $P < .005$). However, below a carapace length of 141 mm, males outnumbered females in each subclass (Fig. 2).

Recaptures.—Eighty-one (46.0%) of the 176 turtles at Sims Pond were captured only once (Fig. 3). The highest number of times captured was eight. At Quahadi Pond, 61 (61%) of the 100 turtles were

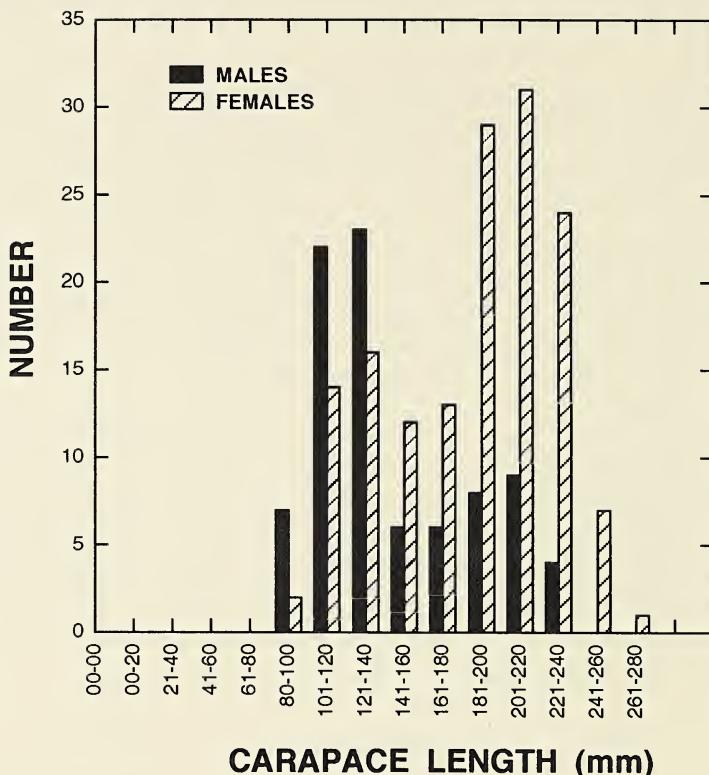


Figure 2. Number of males and females in carapace length categories to show the ontogenetic shift in sex ratios. Data from both ponds combined.

captured only once and the greatest number of times captured was six. The highest number of new captures per day at Sims Pond was 29 (day two) and 23 (day eight). The highest number of new captures at Quahadi Pond was 19 (day five) but 18 new individuals were captured on day two. Over the two year period, only days 16 and 17 failed to produce any new animals at Sims Pond and no new animals were captured on days 13 and 14 at Quahadi Pond.

The percent of marked turtles per capture time at Sims Pond did not exceed the percent unmarked until day four (Fig. 4). Thereafter, except for days six and seven, marked turtles predominated in the samples. At Quahadi Pond, marked turtles did not exceed the percent unmarked (exclusive of day four, when only two turtles were caught) until day nine. The value increased to 100% on days 13 and 14, but was only 43% on day 15.

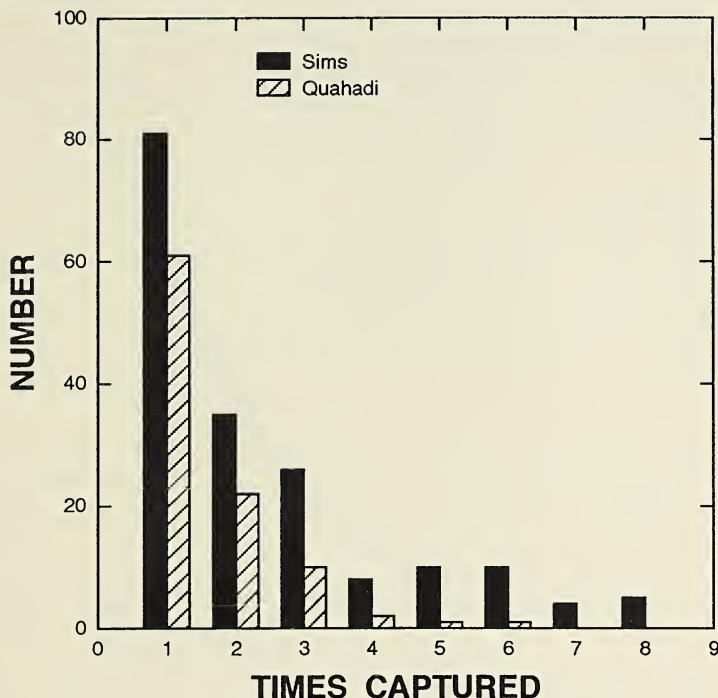


Figure 3. Number of times that individual turtles were captured.

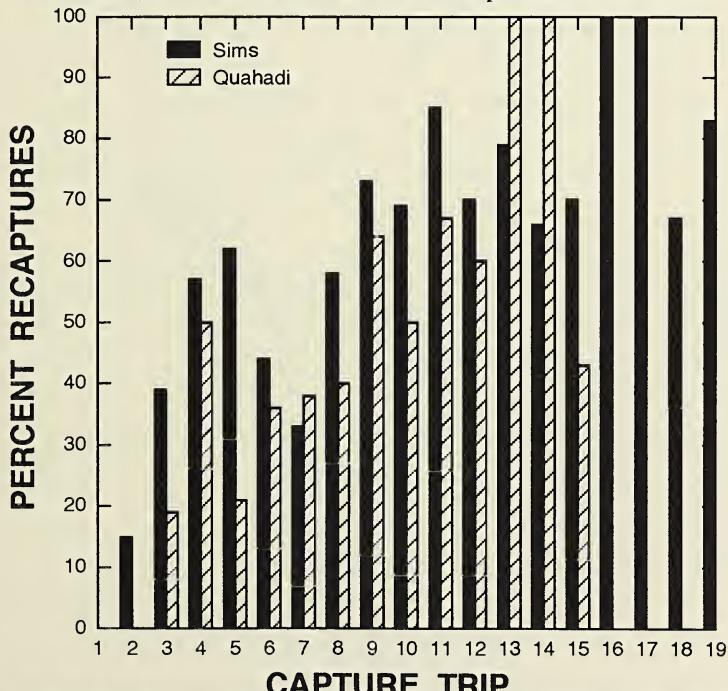


Figure 4. Percent of marked *Trachemys scripta* comprising the sample at each capture time.

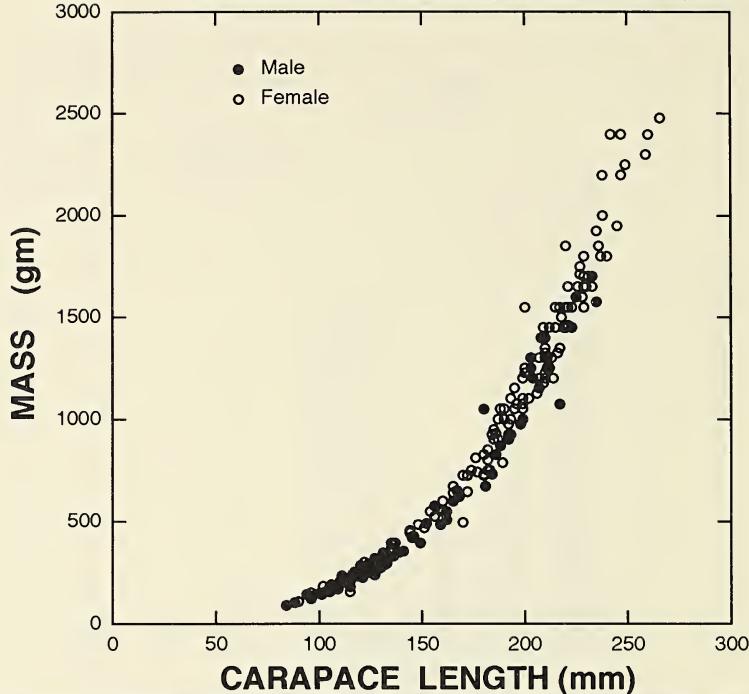


Figure 5. Mass of male and female *Trachemys scripta* versus carapace length. Data from both ponds combined.

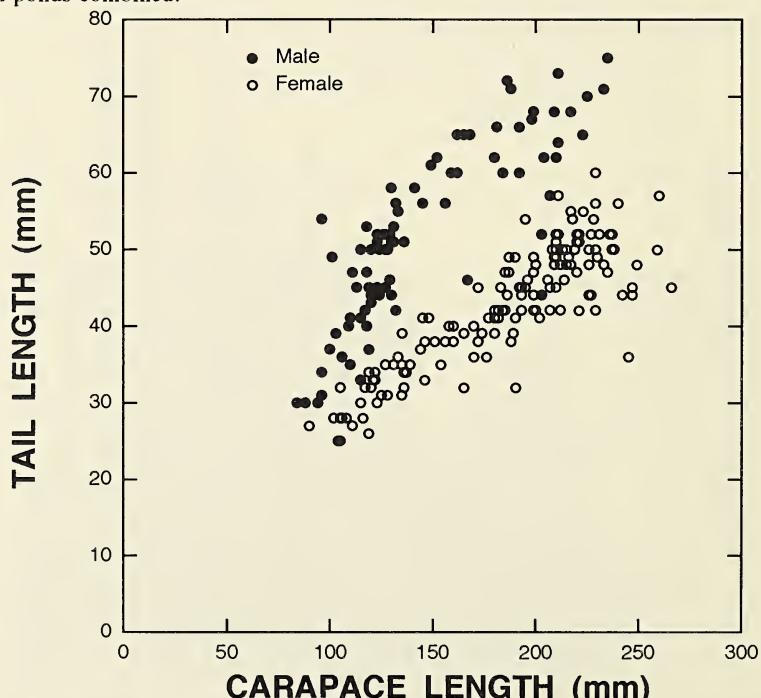


Figure 6. Tail length of male and female *Trachemys scripta* versus carapace length. Data from both ponds combined.

Seventy-three percent of juveniles at Sims Pond and 92.3% of those at Quahadi Pond were captured only once. It appears from these data that juveniles are less likely than females (Sims Pond = 37.1%; Quahadi Pond = 53.7%) or males (Sims Pond = 48.1%; Quahadi Pond = 69.7%) from either pond to be serially captured.

There was a significant difference between females and males regarding numbers of turtles captured three or more times at Sims Pond ($X^2 = 148$; $P < .005$) and at Quahadi Pond ($X^2 = 604$; $P < .005$). These data indicate that although there were fewer males than females captured in each pond, once males were caught, they were also less likely to be recaptured.

Twenty-eight percent of all turtles captured at Sims Pond were taken after the ninth capture day (a similar pattern was found at Quahadi Pond) raising the question of why these turtles were not captured previously. In addition, of the 12 turtles caught on day nine, five were recaptured once, two twice, and one four times during the next six capture trips. Whereas an individual turtle might not be captured early, once it was captured, it was prone to recapture.

Population estimates at Sims Pond.—The population size estimate at Sims Pond was 122 ± 100 turtles. This value has little utility because 176 turtles were marked over the course of this study and it is suspected that the capture of a turtle might affect whether it is immediately recaptured. As mentioned earlier, marked males are less likely to be recaptured than marked females. Also, on capture day 15, 42% of 27 turtles captured were not marked, indicating that animals that had opportunity to enter traps previously had not done so.

Movement between ponds.—Most tank ponds in the Post, Texas area routinely dry, forcing turtles to abandon the sites. Once water becomes available, the ponds are quickly re-populated leading one to believe that most do not move to other ponds, but rather aestivate nearby. Some general movement of turtles occurs during the egg laying season but males rarely are found on ranch roads. Two turtles moved from Sims Pond to Quahadi Pond during this study; both were females. No turtles were observed in the Sims Pond that were originally captured in Quahadi Pond. Certainly there was no migration between ponds that would account for the fact that unmarked animals were captured each of 19 capture days at Sims Pond.

Size relationships.—Females attain a larger body size than males (Fig. 5). Based on carapace length, the largest female measured 31 mm longer than the largest male (female = 266 mm; male = 235 mm). The

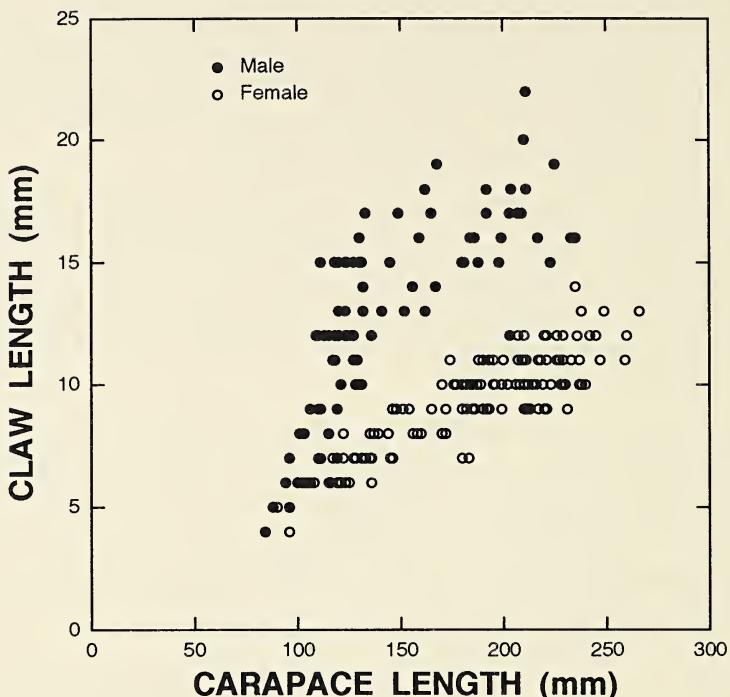


Figure 7. Claw length of male and female *Trachemys scripta* versus carapace length. Data from both ponds combined.

majority of males measured between 101 and 140 mm carapace length, while the majority of females was between 181 and 240 mm. The largest female weighed 2480 gm and the largest male, 1700 gm, a 31.4% difference.

Carapace length was closely correlated with carapace width in both sexes. Weight correlated well with carapace length and exhibited a typical "J" relationship. Individuals exhibited no significant weight changes during the course of the study and weight could not be used as a growth indicator.

Sexual dimorphism.—Relative to body size, males had longer tails than females (Fig. 6), claw length was longer (Fig. 7), and cloacal extension was longer (Fig. 8). Cloacal extension relative to body size was the best indicator of sex of a turtle at the smallest carapace length.

Reproduction.—Only six (30%) of the 20 females x-rayed contained shelled eggs. The lowest number of eggs was three, and the highest was 11 (Fig. 9). One female (carapace length = 210 mm) deposited seven

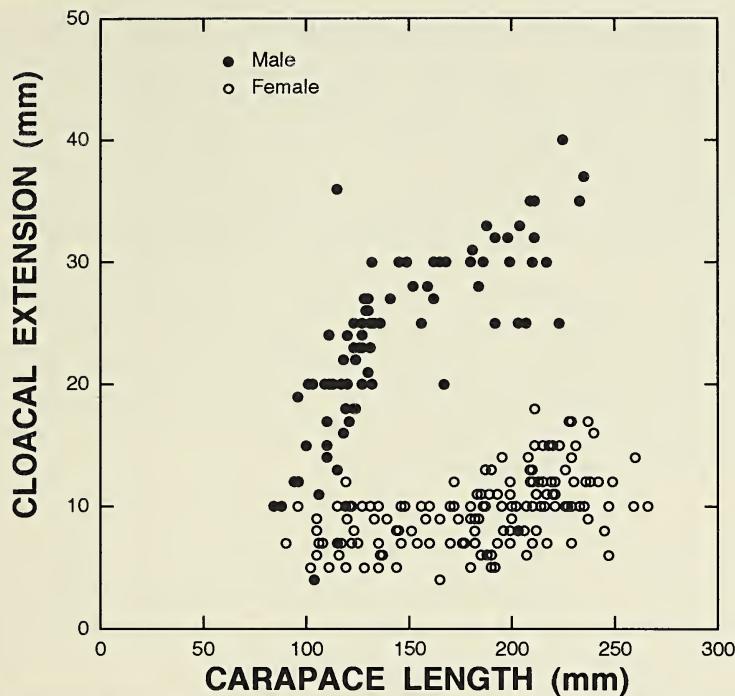


Figure 8. Cloacal extension of male and female *Trachemys scripta* versus carapace length.

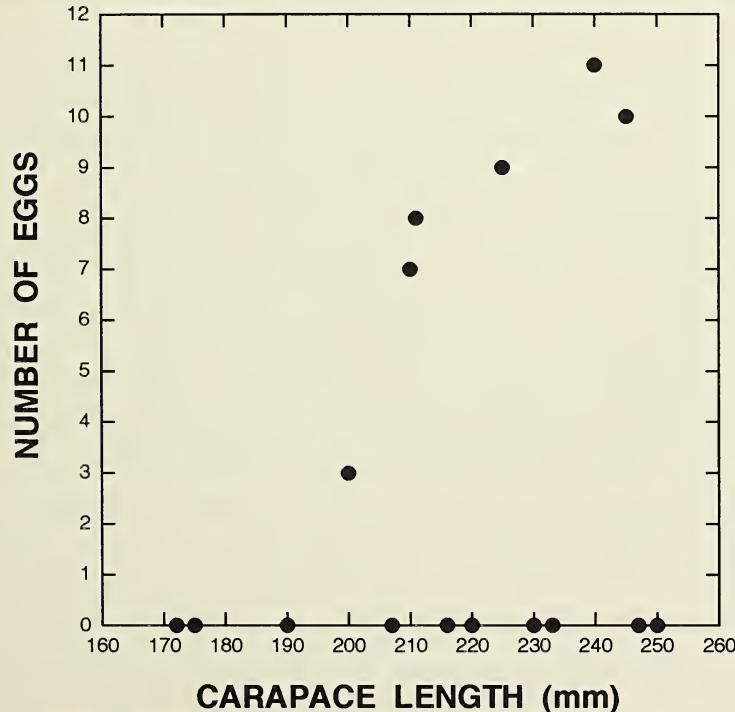


Figure 9. Number of eggs of *T. scripta* as determined by radiography.

eggs before its release. Mean egg width was 21.4 mm (20.7 - 21.9), mean length was 38.2 mm (37.5-39.5), and mean weight was 10.0 gm (9.5 - 10.4). The mean elongation factor (length/width) was 1.7. Only two nests were found during this study; both were destroyed by predators (probably raccoons). One nest was approximately 60 m from water, the other was 52 m. Each nest was dug in dry, compacted soil under the canopy of a mesquite (*Prosopis glandulosa*) shrub.

Densities.—One hundred and eighteen *T. scripta* were captured in Sims Pond in 1988 and 57 individuals in 1989, providing density estimates of 513 per ha and 247 per ha for those two years. Calculated densities at Quahadi Pond were 983 per ha and 333 per ha, respectively. The perceived decrease in density at Sims Pond for the two years was 52%; for Quahadi Pond it was 66%.

Biomass.—Estimated biomass at Sims Ponds was 462 kg/ha in 1988 and 374 kg/ha in 1989; the decrease between years was 19.0%. Biomass estimates for Quahadi Pond were 304 kg/ha in 1988 and 194 kg/ha in 1989; a difference between years of 36.1%. There was a 48.4% difference in calculated biomass between Sims and Quahadi ponds in 1988 and a 59.3% difference in 1989.

DISCUSSION

The Sims and Quahadi ponds are a considerable distance from other surface water. The terrain between these two ponds and other water sources is environmentally challenging other than during periods of rains. In addition, migrating individuals are subject to a host of predators including, coyotes, (*Canis latrans*), raccoons (*Procyon lotor*), badgers (*Taxidea taxus*), foxes (*Urocyon cinereoargenteus*), and bobcats (*Lynx rufus*). It is therefore concluded that it is unlikely that many turtles left the two ponds during this study. The absence of *Kinosternon flavescens* at Quahadi Pond and the presence of only two individuals of this species at Sims Pond over a two year period and the absence of soft shelled turtles (*Trionyx spiniferus*) and snapping turtles (*Chelydra serpentina*) attest to the isolation of the two study ponds.

Adult *T. scripta* are opportunistic feeders but in the study ponds there was little animal protein, causing the turtles to rely on a few plant species that were seasonal in occurrence. As a result, many of the captured animals appeared emaciated. The forelimbs frequently were thin and underling bones were easily felt. On occasion, the forelimbs would flail about when the turtles were pivoted rapidly. It is therefore

concluded that while turtle density was high at both ponds, individuals were not at optimum length-weight conditions. Smaller individuals appeared to be affected most severely by low food availability, possibly accounting for the presumed low numbers of adult males.

If males were more prone to exit a pond in search of females, one would expect a general exchange between ponds supporting the premise that males migrated more frequently than females. Such was not the case as only females were found to have exchanged ponds, and then only two animals. It is suggested that females are more prone to leave a pond when they make treks to lay their eggs. At this time, some females probably do not return to the most recently inhabited pond. If the sex ratios favor females, then males accrue no advantage in leaving a pond with large numbers of females. In fact, they place themselves at higher mortality risk from predation.

That males (and juveniles) are less likely to be recaptured than females might suggest that they are generally less likely to be captured initially. Gibbons (1970) concluded that many previous studies on aquatic turtles, including *T. scripta*, did not convincingly establish sex ratios biased toward one sex. Indeed, if the bias reported here is not reflective of the "true" adult ratio, then differential behavior between the sexes resulting in unequal catchability should be suspect in all such studies. Females might forage longer and more aggressively because of increased metabolic demands associated with egg production. The probability of recapture might be related to whether a reward was obtained in the trap. Those turtles (probably females) arriving first would consume the unsecured bait, leaving only small scraps for any other arrivals plus the unavailable bait in the porous plastic container. Those turtles experiencing confinement, a repetitive odor, and no reward might well shun baited traps. Those aggressive animals arriving early and securing a reward associated with the odor might be inclined to enter the traps readily. Juveniles and smaller males might not be as frequently rewarded in the traps as females, and therefore they would be less likely to re-enter. Individuals eventually entering a trap and being rewarded, and not harmed, might tend to be recaptured. That is, the risk of entering the trap is offset by the reward of increased energy availability. Assuming that females have greater energy needs than juveniles or males, then females as a group might be more prone to be captured in a fixed trap.

Because male *T. scripta* mature at smaller sizes than females, a total sex ratio delineated by size will include sexually immature females

(Gibbons 1970). If one assumes that all males in this study exhibiting secondary sexual characteristics to be sexually mature and one deletes all females with a carapace length less than 161 mm, the adult sex ratio obtained becomes 1 male:1.2 females.

It remains unknown as to why turtles inhabiting what appears to be an environment depauperate in animal protein would not enter traps baited with animal protein. However, on several occasions turtles were observed basking on baited traps. Why an individual would not enter traps for over a year, then be caught several times sequentially is not known. Initially it was thought that the animals had emigrated into the pond during the study but in all cases, the turtles were covered with a mat of algae and mud (about one cm thick) indicating that they had been in the ponds for some time. Once this mud dries it is quite brittle and dissolves readily when exposed to water. This layer was routinely removed from initially caught turtles and it was not reestablished on individuals during the course of the study. Also, because of the isolation of the two ponds, there was no ready source of new turtles.

Densities and estimated biomass values in both ponds are among the highest reported (Iverson 1982; Congdon & Gibbons 1989) for any aquatic turtle species but are underestimated. It is concluded that the population size estimate at Sims Pond was not robust enough to warrant calculation of estimated densities nor biomass. Because the number of marked animals at Quahadi Pond never exceeded the number of new animals captured reservations remain relative to using these data to establish population parameters.

The drastically lower density and biomass calculations for both ponds for the second year of the study is perplexing. There was no suggestion of mass migration as evidenced by dead animals and exchange between the two ponds was minimal. It is possible that turtles died over the course of the study and remained submerged. This is considered unlikely and it is proposed that there was no significant reduction in numbers of turtles, but there was a reduction in their willingness to enter traps. The high percentage of turtles captured only once (46% for Sims Pond and 61% for Quahadi Pond) supports the premise that many turtles shunned traps.

Differences in the body size of males and females was unremarkable for this species (Ernst et al. 1994). Unfortunately, the inability to establish size at sexual maturity prevented a more accurate calculation of adult sex ratios.

The mean number of eggs (eight) was within the range of values for other populations of *T. scripta* (cf. Cahn 1937; Cagle 1950; Carr 1952; Webb 1961; Iverson 1977; Gibbons & Greene 1990). It is feasible that the individual with three eggs recently had deposited a previous clutch or partial clutch. The increase in egg number with increasing size of the females is well documented for this species (Gibbons 1970; Congdon & Gibbons 1983), and many other species of turtles (Ernst et al. 1994).

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**SEXUAL DIMORPHISM IN HEAD SIZE OF THE
MEDITERRANEAN GECKO *HEMIDACTYLUS TURCICUS*
(SAURIA: GEKKONIDAE)**

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Abstract.—Comparisons were made between 53 female and 67 male Mediterranean geckos (*Hemidactylus turcicus*) collected from the campus of Stephen F. Austin State University in Nacogdoches, Texas. Head dimensions (length, depth and width) and weight of adult males and females were compared with analysis of covariance using snout-vent-length as a covariate. Males were significantly larger in head size and weight at a given snout-vent-length. Males and females did not differ significantly in snout-vent-length. Larger heads in males may be the result of sexual selection, as males with larger heads may exhibit greater success in intrasexual encounters. There may also be an ecological advantage for larger body size in females resulting in parallel increases in body size in both sexes. Larger females may produce better quality eggs which may enhance survival rates in offspring.

The Mediterranean gecko *Hemidactylus turcicus* is an introduced lizard native to the Old World that has recently colonized (since the 1920s) the gulf coastal states of the U. S. (Stejneger 1922; Conant & Collins 1991). Some previously identified sexual differences in the gecko include enlarged preanal pores and post-cloacal bones in mature males that are not obvious in immature males and females (Selcer 1986). This study was undertaken to examine body-size dimorphism between adult male and female *H. turcicus* and possible factors related to its origins.

The Mediterranean gecko is known to use its tail in behavioral displays. Klawinski (1991) observed a male gecko tail-waving while engaged in an aggressive intrasexual encounter, while Marcellini (1977) observed a male gecko tail-waving at a female apparently in a courtship display. Although tail-waving has been observed, it is not well studied in this species. There are no investigations into tail-length differences between the sexes.

Head-size dimorphism, which is common in squamates, is a trait that may be influenced by both ecological segregation as well as by sexual selection (Shine 1991). Camilleri & Shine (1990) suggest that head-size dimorphism in some snakes is the result of morphological adaptations for prey-size specialization. Head-size dimorphism in lizards is usually

Table 1. Morphological measurements of adult Mediterranean geckos.

	N	Mean \pm SD	Adjusted Mean	Range
SVL (mm)				
male	67	50.9 \pm 3.77	—	44.0 - 58.0
female	53	51.5 \pm 4.45	—	44.0 - 60.0
Head length (mm)				
male	67	12.4 \pm 1.13	12.5	10.0 - 15.0
female	53	12.2 \pm 1.20	12.2	8.0 - 14.0
Head width (mm)				
male	67	10.1 \pm 0.90	10.1	8.0 - 12.0
female	53	9.7 \pm 0.99	9.7	7.0 - 12.0
Head depth (mm)				
male	67	6.5 \pm 0.84	6.5	4.0 - 8.0
female	53	6.1 \pm 0.86	6.1	4.0 - 8.0
Tail length (mm)				
male	52	52.4 \pm 6.31	52.4	31.0 - 64.0
female	42	51.0 \pm 8.47	50.9	28.0 - 66.0
Weight (g)				
male	67	3.5 \pm 0.94	3.6	1.9 - 5.8
female	53	3.4 \pm 1.02	3.4	1.4 - 5.6

attributed to sexual selection or resource defense where males with larger heads are more successful in intrasexual confrontations (Carothers 1984; Vitt & Cooper 1985; Hews 1988; Smith 1992; Mouton & Wyk 1993).

METHODS AND MATERIALS

Geckos were collected on the campus of Stephen F. Austin State University in Nacogdoches, Nacogdoches County, Texas (94°W longitude and 31°N latitude). All geckos ($N = 200$) were taken after sunset between 1844 and 0045 hrs from 19 April to 15 October 1990. The first 15 geckos encountered during a sampling session were collected.

Specimens were returned to the lab where snout-vent-length (SVL), head length (measured from the base of the skull to the tip of the snout), head depth (measured from the deepest part of the head), head width (measured from the widest part of the head), and tail length (measured from the vent to the tip of the tail) were measured to the nearest 1.0 mm with dial calipers, and they were also weighed to the nearest 0.1 g. All geckos were measured (and weighed) before they were preserved. Individuals ≥ 44 mm SVL were considered adults (Selcer 1986). All lizards with broken or regenerated tails were excluded from testing for

Table 2. Analysis of covariance comparing morphological characters of adult male and female Mediterranean geckos using SVL as a covariate.

Morphological character	F	df	P
Head length	3.96	117	0.0491
Head depth	12.35	117	0.0006
Head width	15.18	117	0.0002
Tail length	1.17	91	0.2829
Weight	5.82	117	0.0174

tail length differences. Sex was determined using the presence of preanal pores to identify males. Only adult males and females were used for statistical comparisons. A two-tailed *t*-test was used to evaluate differences in SVL between adult males and females. Analysis of covariance was used to compare differences in body size (head width, head length, head depth, tail length and weight), using SVL as a covariate, between adult male and female geckos ($P < 0.05$ was considered significant).

RESULTS

One hundred and twenty of the 200 geckos collected were identified as adults, using 44 mm SVL as a minimum size (Selcer 1986). Adult female geckos ($N = 53$) on average had a slightly longer SVL than males ($N = 67$) (Table 1), but the difference was not significant ($t = 0.7927$, $P = 0.2148$). Twenty-two percent of all adult males had broken or regenerated tails compared to 20.8% for all adult females. Relative tail length of males was slightly longer than females, but not significantly larger ($t = 1.2336$, $P = 0.1103$). Head dimensions (length, depth and width) and weight of adult males and females were significantly different, with males being larger at a given SVL (Table 2).

DISCUSSION

Male specimens examined during this study were significantly heavier than females at a given SVL (Table 2). This difference may be caused by weight loss of females following oviposition, therefore no conclusions are proposed relative to sexual selection of body mass.

Klawinski (1991) suggested that Mediterranean geckos may be territorial, demonstrated by low home range overlap and observations of intrasexual aggression in males. He also found that the males of this

species emerge from winter retreats earlier than females, possibly to establish territories prior to the breeding season. Although there have been no studies conducted on this species concerning mate acquisition, it is possible that sexual dimorphism in head size in *H. turcicus* (males having the significantly larger heads) may be the result of sexual selection. This is based on studies of other species of lizards that exhibit sexual dimorphism in head size. Hews (1988) found that most female *Uta palmeri* mated with the owner of a territory and found that territorial males had larger heads than non-territorial males. Carothers (1984) studied 11 species of herbivorous lizards and found that low male aggression species have little or no head-size sexual dimorphism, while the aggressive male species showed significant differences in head and body size between males and females.

Another possible influence on head-size dimorphism may be ecological segregation. Saenz (1992) suggests that, while there is some evidence indicating differences in the diets of male and female Mediterranean geckos, the differences are probably due to differences in microhabitat selection because female geckos consumed the same size prey items as males.

If sexual selection has lead to the evolution of head-size dimorphism between the sexes of *H. turcicus*, the similarity of SVL between sexes remains unexplained. If there is competition among males for mating opportunities, selection for larger males might be expected. Why then, are females not smaller than males? A possible answer is that there is also an ecological advantage to larger body size in females resulting in parallel increases in body size in both sexes, where both sexes have reached their maximum size due to niche and habitat constraints but from different selective pressures. Increased body size in some lizards and snakes has been shown to be positively correlated with increased fecundity (Cuellar 1984; Shine 1986; Ford & Seigel 1989; Vial & Stewart 1989; Taylor et al. 1992). In temperate climates *H. turcicus* has a fixed reproductive output of two clutches per year (possibly more in tropical climates) and a fixed clutch size of two eggs (Selcer 1982), therefore, body size can not influence fecundity. Although fecundity is not related to female body size, there still may be some advantages. Selcer (1990) stated that larger Mediterranean geckos produce more lipid in their eggs, thus, larger females may produce better quality eggs, which may transfer a higher survival rate to offspring.

There may be converging selective pressures for larger body size in male and female Mediterranean geckos based on available behavioral

studies and morphology. Because the morphometric differences between sexes were small (Table 1), conclusions resulting from statistically significant differences must be tempered with biological meaningfulness. Hence, there may be some uncertainty of the biological significance of the morphometric differences detected in this study. In order to better understand the origins of sexual dimorphism in this species, selective pressures should be examined more closely for both sexes, specifically head size in males as it relates to mate acquisition and lipid mass in eggs as it relates to survivorship of young.

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A SEROLOGICAL ANTIBODY SURVEY FOR HIV-1 AND HEPATITIS B IN NORTHERN CHIHUAHUA, MEXICO

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Abstract.—Serum samples collected from two geographically distinct populations in the state of Chihuahua, Mexico (Chihuahua City and the Tarahumara Indian village of Bahuinocachic) were tested for human immunodeficiency virus type one (HIV-1) and total hepatitis B core antibodies. Positive rate for hepatitis B antibody was 8.5% and 3.4% in Bahuinocachic and Chihuahua City, respectively. Presence of antibody in relation to age, sex, and place of residence revealed age to be the only significant factor. All samples were negative for HIV-1.

Resumen.—Las muestras de suero de las dos poblaciones geográficamente distintas de Chihuahua, México (la ciudad de Chihuahua y Bahuinocachic que es un pueblecito de los indios Tarahumara) fueron analizadas para los anticuerpos del virus HIV-1 y la hepatitis B. La incidencia de la hepatitis B fue del 8.5% en Bahuinocachic y 3.4% en Chihuahua. La presencia del anticuerpo con respecto a la edad, sexo, y residencia de los individuos reveló que la edad era el único factor significativo. Todas las muestras fueron negativas para HIV-1.

Human immunodeficiency virus (HIV) and hepatitis B virus (HBV) are sexually transmitted through infectious body fluids, parenterally via contaminated blood and blood products, and perinatally from mother to child. Both infectious diseases can produce severe socioeconomic damage, particularly in third world nations. Serological surveillance is an important tool in establishing the presence and frequency of disease. Prevention and control measures through education and/or vaccination can then be implemented.

Detectable antibodies (IgG) to HIV usually develop within one to three months after initial infection at approximately the same time as onset of acute mononucleosis-like symptoms, although one study (Imagawa et al. 1989) of high-risk individuals reports antibody production may not occur for up to three years. Immunosuppressed patients receiving organ transplants with HIV may have a long delay in antibody production (Rubin & Tolkoff-Rubin 1988). Conversely, seroconversion to antibody negative status in asymptomatic individuals with evidence of HIV has been reported (Farzadegan et al. 1988). Loss of ability to produce antibodies to HIV indicates a grave prognosis (Levinson & Denys 1988).

Cumulative totals for AIDS cases in the United States as of December

1994 were 441,528 with 270,870 deaths. Men still account for the majority (82%) of AIDS cases with 44% of the cases reported being homosexual men, however, AIDS cases associated with heterosexual transmission, particularly among black and Hispanic women, has been increasing. Accordingly, pediatric cases in children less than 13 years of age experienced an 8% increase from 1993-1994 with 92% being perinatally transmitted. The incidence rate of AIDS is 6 times higher in blacks and 3 times higher in Hispanics than among whites, probably reflecting different socioeconomic or cultural factors (CDC 1994).

Reported cumulative totals of AIDS cases through December 1994 for Hispanics in the United States were 76,323 with 45,064 deaths. The 30-39 age group in both sexes had the highest rates with the majority of cases being men who are at risk through homosexual or bisexual behavior and/or intravenous (I.V.) drug use. Exposure for women is mainly from I.V. drug use and heterosexual contact (CDC 1994).

AIDS cases reported by 30 June 1993 in Chihuahua, Mexico totaled 184 statewide accounting for 1.3% of all cases in Mexico. As in the United States, males comprised the majority of cases in Mexico with the highest incidence rate in the 25-39 year old age group for both sexes (Ostolaza-Calvillo 1993).

Antibody production to hepatitis B core antigen (anti-HBc) is detectable following a 4-12 week incubation period. As IgM antibody production is switched to IgG, total anti-HBc remains detectable lifelong, and is an indicator of current or previous infection (Coslett 1990).

In the United States HBV presents a major health problem and worldwide is the main cause of acute and chronic hepatitis. In the United States, Western Europe and Australia, infection primarily occurs during adulthood with a resulting 0.2-0.9% chronic carrier rate. Sources of infection of most cases are I.V. drug users (28%), heterosexual contact with infected persons or multiple partners (22%), and homosexual activity (9%) (CDC 1990).

Many chronic carriers are at risk for long-term sequelae such as primary hepatocellular carcinoma and cirrhosis (Maynard et al. 1988). In the United States, 6-10% of infected adults, 25% of children age 1-5, and 70-90% of infected infants, result in chronic infection (Maynard et al. 1988; McMahon et al. 1984; Beasley et al. 1983). It is estimated that in the United States each year 300,000 persons, mainly young adults are infected. There is an estimated pool of 750,000-1,000,000 potentially infectious carriers in the United States (CDC 1991).

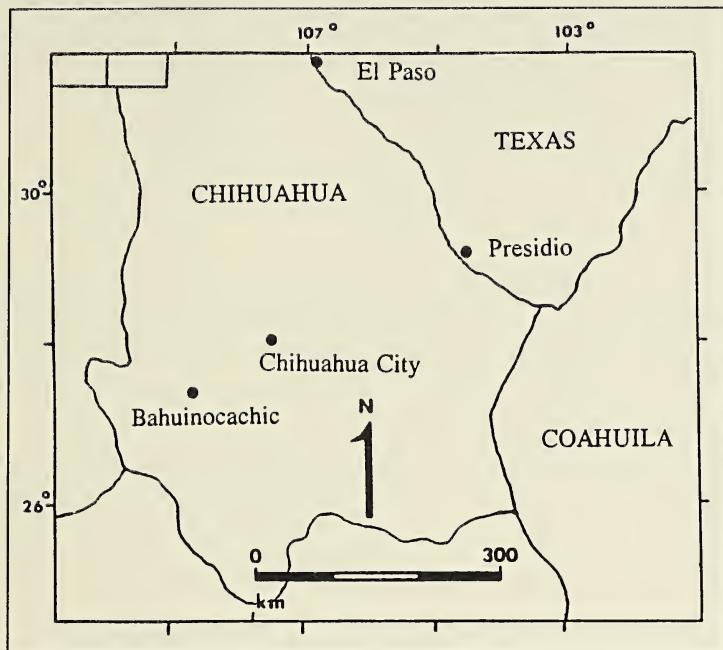


Figure 1. Serum sample collection sites in Chihuahua, Mexico.

This study was intended to determine and compare the presence of antibodies to hepatitis B core antigen and HIV-1 in two distinct geographic regions and ethnic populations from the northern state of Chihuahua, Mexico. The Tarahumara Indians from Bahuinocachic comprised one group. The second sample population obtained in Chihuahua City included mainly Mexican nationals of Spanish decent.

MATERIALS AND METHODS

A total of 146 serum samples from two regions (Fig. 1) were collected during August 1992. Eighty-seven were acquired from the Clinicas las Americas in Chihuahua City, Mexico. The remaining 59 samples were obtained during a medical missionary trip to a Tarahumara Indian village in Bahuinocachic, Mexico. The decision was made to collect blood only from patients in the village that were 16 and older.

All samples were drawn aseptically by venipuncture in a plain, sterile vacutainer tube, allowed to clot, and centrifuged at 1,500 rpm for five minutes. Serum was transferred to sterile plastic stoppered vials. Samples from Bahuinocachic were stored on dry ice. Samples from

Table 1. HBV core antibody: The number of samples, number of positives and percent positive rate by location.

Location	Number of Samples	Number of Positives	Percent Positive
Bahuinocachic	59	5	8.5%
Chihuahua City	87	3	3.4%

Chihuahua City were stored in a refrigerator-freezer during the collection period and subsequently transferred to dry ice upon receipt. All samples remained on dry ice during the return trip and were then stored at -70 degrees C until testing. Age, sex and reason for visiting the clinic were recorded for all samples.

Antibody testing for HIV-1 (IgG) and total hepatitis B core antibody (IgG and IgM) was performed according to the package inserts of the Human Immunodeficiency Virus Type 1 HIV-1 EIA (Abbott 1989) and Hepatitis B Core Antigen (Recombinant) Corzyme (Abbott 1990).

RESULTS

Of the 146 serum samples from Mexico examined for HIV-1 and hepatitis B core antibodies, Bahuinocachic had an 8.5% positive frequency for hepatitis B core antibody; with Chihuahua City having a positive frequency of 3.4%. Table 1 illustrates the percent positive frequency of hepatitis B core antibody by region. To determine if geographic location had a significant outcome on antibody presence, Chi-square analysis was performed. No significant relationship was evident with Chi-square equaling 1.8 ($p > 0.05$). Both locations were negative for HIV-1 and not considered for statistical analysis.

The correlation of a positive antibody test and sex was investigated. Males were positive at a frequency of 7.7% (2 of 26) and 6.9% (3 of 43) in Bahuinocachic and Chihuahua City, respectively. Females in Bahuinocachic had a positive frequency of 9.1% (3 of 33) with no female positives in Chihuahua City. Both groups showed no correlation between sex and antibody prevalence with Chi-square being 0.7 ($p > 0.05$).

Table 2 summarizes the relationship of age and sex to presence of antibodies in Bahuinocachic and Chihuahua City. For the 20-29 age group, 16.7% were positive as compared to 15.8% for 40-49. No other age groups were positive. Statistical analysis resulted in a Chi-square

Table 2. HBV core antibody: The number of samples, number of positives, and percent positive by sex and age in Bahuinocachic and Chihuahua City.

Age Group	Number of Samples	Number of Positives		Percent Positive
		Male	Female	
0-9	3	0	0	0
10-19	11	0	0	0
20-29	30	3	2	16.7%
30-39	36	0	0	0
40-49	19	2	1	15.8%
50-59	26	0	0	0
60+	21	0	0	0

value of 15.8 ($p < 0.05$), indicating age is a significant factor in antibody prevalence.

DISCUSSION

The overall positive frequency of both locations for total hepatitis B core antibody was 6%. Within the two groups Bahuinocachic had 8.5% and Chihuahua City 3.4% positive frequency. In a similar study Gordan et al. (1990) determined the seropositive frequency in serial unselected admissions to a Veterans Administration hospital in Washington, D.C., to be 2.0% for hepatitis B and 3.7% for HIV. The study population was 65% black, 98% male, and had an average mean age of 59.5 years (range of 21-96). Average age from both locations of Mexico was 39.4 (range of 4-76). The higher positive frequency in Bahuinocachic could be due to the isolation of a small population that rarely marries outside the village and multiple marriages, although the statistical data indicated no significant factor caused by location.

The 20-29 age group had the highest positive frequency (16.6%) followed by the 40-49 age group (15.8%) for both study populations. This correlates well with the fact that hepatitis B infections occur more frequently in young adults who have increased sexual activity or who are more likely to engage in high risk activities.

The lack of seropositivity of HIV-1 is expected particularly in the isolated Bahuinocachic group. The small number tested (59) could be a factor, although the number comprised more than 40% of the village of about 150 people (Jim Perkins, pers. comm.).

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REPLACEMENT CHERT IN THE ALIBATES DOLOMITE (PERMIAN) OF THE TEXAS PANHANDLE

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Abstract.—In the Panhandle of Texas, chert replacement of the Alibates Dolomite (Guadalupian-Ochoan) has produced spherules (less than 5.0 mm), irregular nodular and podlike masses, and massive tabular sheets. Chert spherules disseminated throughout the upper and lower dolomite units are composed of quartzine (length-slow) and chalcedony (length-fast). Relic fibrous textures and ghost crystal outlines suggest that quartzine spherules probably are evaporite replacements. Chalcedony spherules are mostly cavity fillings with iron oxide stained growth rings that show multiple stages of infilling. Chertification in places along fractures and porous zones in the dolomite units has produced pod-like chert masses with entrapped "islands" of dolomite. In the Alibates Flint Quarries National Monument and vicinity, chert has replaced the upper dolomite unit in an exposed area of several square kilometers. Lamination, brecciation, and other sedimentary features of the dolomite are well preserved in this massive sheet of microcrystalline quartz. Although the sources of silica are not definitely known, the results of this study suggest that sources for most of the silica were stratigraphically above the Alibates. As evidenced by massive chert in the upper dolomite member, the Alibates appears to have been replaced locally by silica-bearing fluid descending from overlying Mesozoic and Tertiary strata. The close proximity of most Alibates chert to opalized and calichified zones in the superjacent Miocene-Pliocene Ogallala Formation suggests that local chertification may have been a by-product of the calichification process. Oxygen isotope ratios of Alibates chert and overlying Ogallala chert are similar but are not definitive.

The Permian Alibates Dolomite crops out along the Canadian River and its tributaries at places where the Canadian River has cut a wide valley into the High Plains of the Texas Panhandle (Fig. 1). At most places along the valley, the resistant Alibates Dolomite forms caps on steep bluffs that overlook the river, and isolated outcrops of Alibates occur along the Salt Fork of the Red River (Barnes 1968).

More than 12,000 years ago, local natives started to quarry chert from a small Alibates-capped hill within the Canadian River Valley, and tribes continued to quarry the colorful chert for weapons and tools into historic time. These quarry pits, which have been identified by archeologists as some of the oldest in North America, are now protected in the Alibates Flint Quarries National Monument near Fritch, Texas.

The Alibates Dolomite was named and first described by Gould (1907) for exposures of the dolomite along Alibates Creek in Potter County, Texas. The type section is along the creek about 2 km south

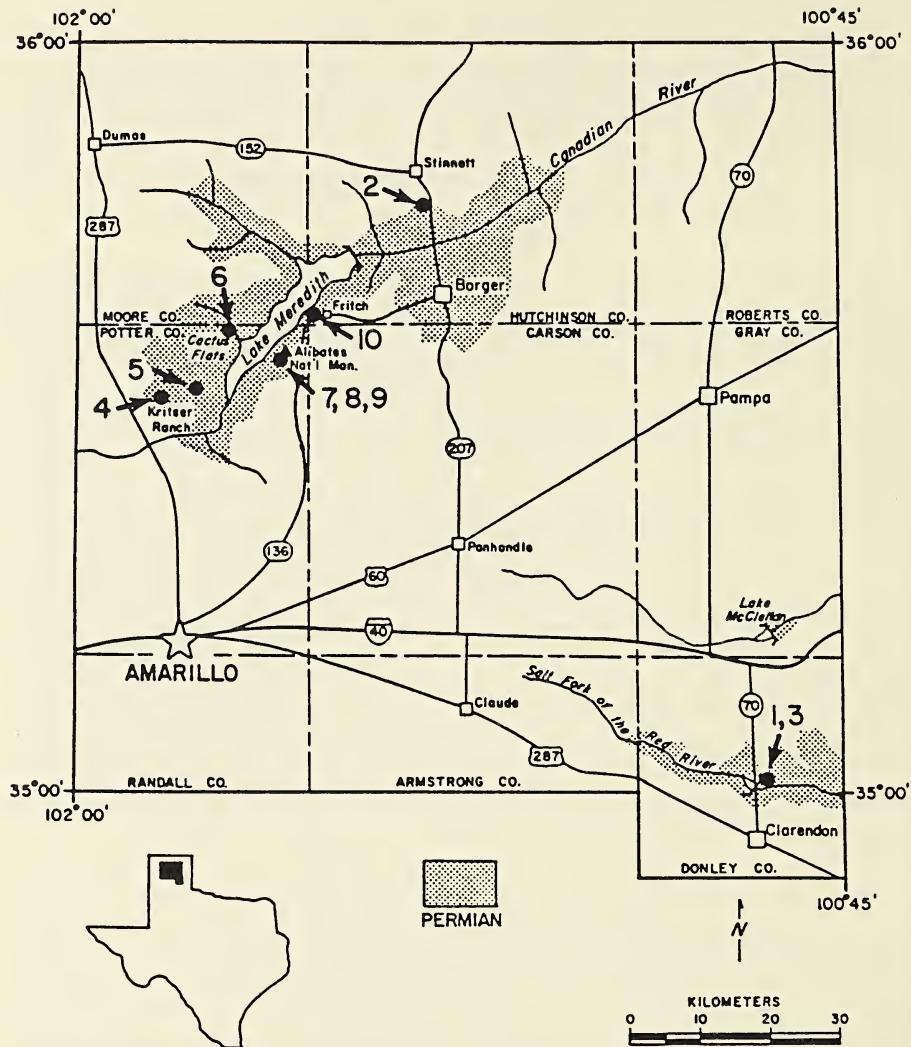


Figure 1. Map of study area showing outcrop of Permian strata. Geology from Barnes (1968;1969). Permian rocks include Quartermaster, Alibates, Whitehorse formations. Numbers show locations of Alibates and Ogallala chert samples selected for oxygen-isotope analysis.

of Alibates National Monument. According to Hertner (1967), the term "Alibates" was a modification of the name Allen Bates, the son of a local rancher (Bowers 1975). Patton (1923) was the first to discuss the origin of the Alibates chert. He presented three hypotheses, including a replacement theory, for the genesis of the chert but did not find evidence to support any of them. Little else had been done until Eifler

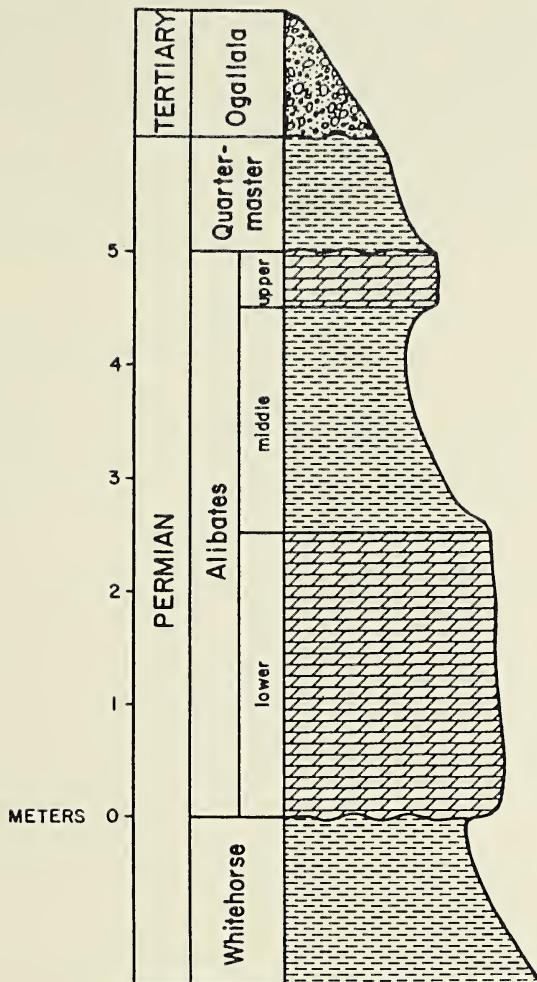


Figure 2. Generalized stratigraphic column showing rocks exposed in study area. Key to lithology patterns as follows: conglomerate and sandstone (open ellipses and dots); dolomite (slanted brickwork); mudstone/shale (horizontal dashed lines).

(Barnes 1969), and Bowers & Reaser (1974) described the chert in the Alibates Flint Quarries National Monument area and suggested a replacement origin.

The primary objectives of this study were to determine the petrography of the chert and chert/dolomite contact zones, and interpret the probable origin of the chert. Thirty stratigraphic sections were measured and studied to obtain a representative geographic distribution over the Alibates outcrop area, and samples were taken from each

sequence of beds. More than a hundred thin sections of selected samples of dolomite, chert, and red beds were examined with a petrographic microscope. Fifteen selected samples of dolomite and chert from the Alibates were analyzed chemically for major elements and certain trace elements. Ten samples of chert-bearing rocks were selected for oxygen-isotope analysis. In addition, six representative samples of dolomite were analyzed for strontium isotopes.

STRATIGRAPHY

The 5.0 m thick Alibates Dolomite is herein subdivided into three informal members: lower gray dolomite, middle red beds, and upper gray dolomite (Fig. 2). The lower member ranges in thickness from 1.0 to 3.0 m and is composed of medium- to finely crystalline dolomite that is distinctly laminated at most places. It is resistant to weathering and forms prominent ledges throughout the study area. The upper 10 to 30 cm of the lower dolomite commonly grades into the overlying middle red-bed member, which is relatively uniform in thickness, averaging 1.5 m. The red-bed lithology is chiefly red to brown, calcareous mudstone. Bedding or lamination is not readily apparent at most localities, but the mudstone does grade into shale at a few places. The mudstone weathers easily, and the contact with the upper dolomite member is marked by a sharp break in outcrop profile. The upper dolomite averages 0.6 m thick and is locally absent. This medium- to finely crystalline dolomite member characteristically is laminated and is intensely brecciated and fractured at some places, causing it to be less resistant to weathering than the lower dolomite member.

In the study area, the Alibates is underlain by red beds of the Permian (Guadalupian) Whitehorse Formation, and at most places is unconformably overlain by the Permian (Ochoan?) Quartermaster Formation, a red-bed interval very similar to the Whitehorse. The Quartermaster is difficult to distinguish from the Whitehorse except by stratigraphic position. Lithologically, these rock bodies are nearly identical, and it is possible that, at places where the Alibates has been removed by erosion, the Quartermaster lies directly on the Whitehorse but has not been recognized. There is also little petrographic difference between the Quartermaster and Whitehorse except that, in places, the Quartermaster may contain more clay and mica than the Whitehorse.

Dixon (1967) reviewed the problem of Alibates correlation and stated that the Quartermaster and Alibates could be either Guadalupian or Ochoan. The Texas Bureau of Economic Geology (Barnes 1969) mapped the Quartermaster, Alibates, and Whitehorse simply as a single

Table 1. Strontium isotope ratios for selected samples of Alibates Dolomite.

Upper Dolomite		Lower Dolomite	
Unit	$^{87}\text{Sr}/^{86}\text{Sr}$	Unit	$^{87}\text{Sr}/^{86}\text{Sr}$
(top)	0.70731	(top)	0.70707
(middle)	0.70734	(middle)	0.70711
(base)	0.70729	(base)	0.70704

Limit of analytical error = +/- 0.00003. Laboratory techniques used in sample analyses are discussed by Burke (1982) and others.

undivided Permian-age formation. A study by Rascoe & Barrs (1972) placed the Quartermaster, Alibates and Whitehorse in the Guadalupian Series, but more recent studies (McGillis & Presley 1981; Presley 1987) have placed the Alibates as a separate formation in the Ochoan Series.

Six samples of Alibates Dolomite collected during this study were selected for strontium isotope analysis. According to Hetherington (pers. comm.), strontium-isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) of the selected samples indicate that both dolomite members were deposited in marine waters late in the Permian Period. As shown in Table 1, there is a marked difference in isotope ratios between the upper and lower dolomite. The lower dolomite is possibly Guadalupian; the upper dolomite probably is Ochoan.

Bowers (1975) proposed a sabkha-like depositional environment for the Alibates because of the prominent algal-mat characteristics displayed by both dolomite members, and because of the local and regional Permian stratigraphy. Although no evaporite minerals were found in the dolomite or chert during this study, the Alibates does contain anhydrite and gypsum outside the study area. McGillis & Presley (1981) described the Alibates from well logs, samples, and cores, and reported that the Alibates thickens southward into the Palo Duro basin and the lithology grades from dolomite into anhydrite and gypsum. They reported laminated anhydrite and gypsum in a core from a well in Randall County about 50 km south of the Alibates National Monument. Additional study of well data by Presley (1987) has detailed extensive evaporite-basin deposition in the Texas Panhandle, and he suggests that much of the Alibates may have been deposited as gypsum.

All Permian formations are unconformably overlain by the Miocene-Pliocene Ogallala Formation. Although the Ogallala Formation is from

Table 2. Chemical analyses of selected Alibates chert and dolomite samples (Mineral Studies Laboratory, Bureau of Economic Geology, The University of Texas at Austin, 1974).

Sample ^A	Member	Al ₂ O ₃	CaO	Fe ₂ O ₃	MgO	MnO ₂	SiO ₂	SiO	TiO ₂	H ₂ O	Ign Ls. ^B	Total
P-1-6	Upper	0.150	30.200	0.060	20.500	0.060	1.590	Tr	0.000	0.240	46.890	99.690
P-2-3	Lower	0.150	30.100	0.100	21.300	0.080	0.850	Tr	0.000	0.160	47.130	99.870
P-2-F1	Lower	0.150	20.100	0.200	13.900	0.055	33.500	Tr	0.000	0.230	31.440	99.575
P-4-4	Lower	0.250	31.400	0.080	19.400	0.150	1.850	Tr	0.000	0.190	46.070	99.390
P-9-4	Lower	0.150	30.000	0.120	20.900	0.060	1.180	Tr	0.000	0.180	46.780	99.370
P-9-9	Upper	0.250	52.800	0.070	1.500	0.120	2.160	Tr	0.000	0.190	42.080	99.170
P-9-F1	Upper	0.200	0.130	0.195	0.020	0.003	98.100	0.000	0.015	0.230	0.940	99.833
P-9A-1*	Lower	0.200	29.700	0.130	21.000	0.025	1.910	Tr	0.000	0.240	45.980	99.185
P-9A-F1*	Upper	0.200	0.130	0.140	0.020	0.007	98.300	0.000	0.020	0.390	1.030	100.237
M-2-3	Lower	0.250	29.500	0.110	21.200	0.060	2.280	Tr	0.000	0.180	46.250	99.830
M-2-5	Upper	0.250	26.700	0.080	19.900	0.040	12.900	Tr	0.000	0.210	39.770	99.850
H-5-2	Lower	0.150	35.500	0.090	15.800	0.060	2.260	Tr	0.000	0.160	45.420	99.440
H-10-2	Lower	0.150	29.900	0.090	21.100	0.045	1.180	Tr	0.000	0.190	46.870	99.525
C-1-2	Lower	0.200	29.500	0.120	21.100	0.060	1.460	Tr	0.000	0.180	46.250	98.870
D-1-4	Lower	0.050	24.200	0.050	17.400	0.075	17.000	Tr	0.000	0.210	38.960	97.945

^A Sample designation indicates county (P-Potter; M-Moore; H-Hutchinson; C-Carson; D-Donley), measured section, and unit; for detailed description refer to Bowers (1975).

^B Ign. Ls. = Ignition Loss.

* Chert sample from Alibates Flint Quarries National Monument.

46 to 91 m thick throughout the southern Great Plains, no thick sections of Ogallala are present in the study area. The Ogallala is easily distinguished from the other formations by its light brown to buff color and by its conglomeratic phases. Locally, the formation consists of carbonate-cemented sandstone and sandy conglomerate. Caliche deposits are well developed at some localities (Brown 1956) and opalization has occurred sporadically in the formation. The opal is similar in appearance to chert in the Alibates. At most places along the Canadian River Valley where the Ogallala has been eroded and Alibates caps the bluffs, Ogallala sand has been "piped" downward into fractures in the underlying rocks, and Ogallala pebbles and cobbles partly cover the Permian strata. It is at localities where the Alibates is directly overlain by Ogallala that the most extensive chertification has taken place.

The Alibates is best known for its chert because of the ancient flint quarries, and yet the chert accounts for probably no more than two or three percent of the total exposure of Alibates. Chert occurs in most outcrops of the Alibates, and although much more abundant in the upper member, it is not confined to any particular bed or stratigraphic horizon in the dolomite. Three habits of chert observed in outcrop are small spherules (< 5 mm), irregular nodular and pod-like masses, and massive tabular sheets. Small chert spherules are most common in the lower dolomite and can be found in almost every outcrop. Irregular masses also occur in both dolomite members, but these bodies are predominant in the upper dolomite. Massive sheets have been found only at two localities: Cactus Flats and the Alibates Flint Quarries National Monument. There, chertification has taken place most extensively and chert has completely replaced the upper dolomite member (Bowers 1975).

Table 2 shows the chemical composition of Alibates rocks. Samples for analysis were chosen to obtain the best geographical distribution over the outcrop area and the most typical or representative rock types from measured sections. The object of the analyses was to determine if any unusual elements or elemental relationships exist in the dolomite and chert. Two chert, one upper dolomite, and two lower dolomite samples were selected from the National Monument because of the archaeological significance. Eight additional samples of the lower dolomite were selected to give the widest possible geographic coverage. The lower dolomite was used because it is more continuous over a large geographic area, whereas the upper dolomite is absent at some places. Two additional samples of the upper dolomite were chosen at random.

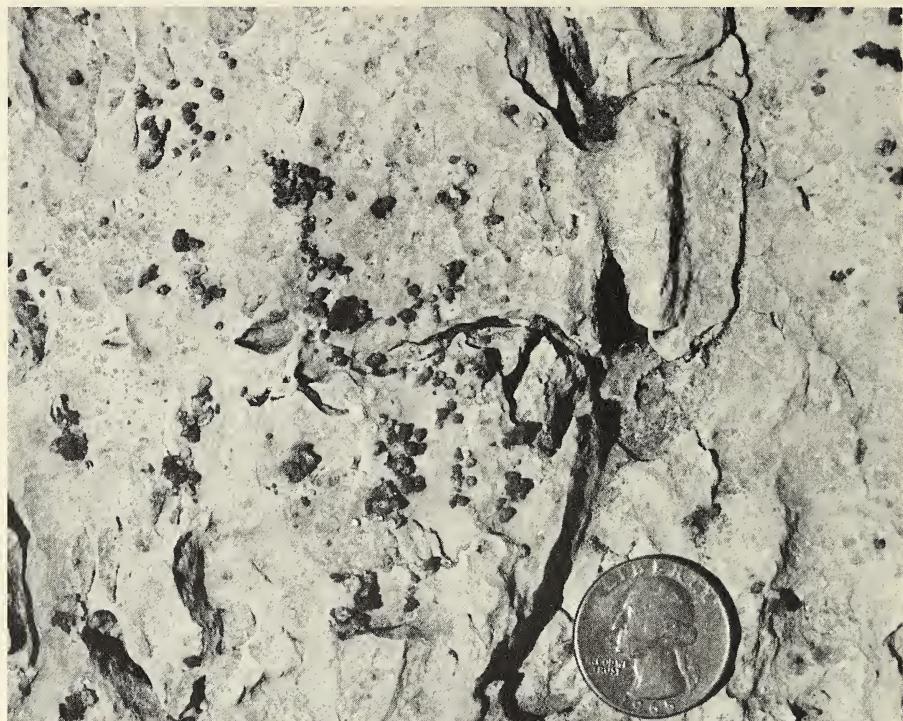


Figure 3. Photograph of scattered chert spherules in the lower dolomite member, Alibates Flint Quarries National Monument. Diameter of coin is 24 mm.

No unusual results were obtained from the analyses. Calcium/magnesium ratios of the dolomite samples range from 1.341 to 2.246 and indicate an excess of calcium in the samples analyzed. Excess calcium would be expected in dolomite that contains cavity filling spar or that has been calcitized. Some rocks are chertified dolomite (10 to 50% silica) and represent both intermediate stages of chertification and transitional contact zones between chert and dolomite rock. Chemical analyses of massive chert from the Monument area show relatively pure silica with no unusual impurities. The two samples (P-9-F1 and P-9A-F1) average 98.2 % SiO_2 with small amounts (0.2% or less) of Al_2O_3 , Fe_2O_3 , CaO , MgO , and TiO_2 .

PETROGRAPHY

The grain-size classification used in this study is that of Folk (1965) as modified by McBride and Thomson (1970) for chert. The following types of authigenic quartz are recognized:



Figure 4. Photomicrograph of chert spherule in lower dolomite member composed of megaquartz (center) surrounded by quartzine and lutecite fibers. Crossed nicols.

Megaquartz: equant to elongated grains larger than 35 microns that commonly occur as cavity and vein fillings.

Microcrystalline quartz: equant grains smaller than 35 microns that commonly form pinpoint-birefringent aggregates.

Chalcedony: radiating fibers, length-fast, extinction parallel with fibers.

Quartzine: fibrous, length-slow, extinction parallel with fibers.

Lutecite: pseudofibrous, length-slow, oblique extinction.

Chert spherules.—Spherules of chert average 2.0 mm in diameter and commonly weather dark brown, giving the appearance of beads in the light gray dolomite (Fig. 3). Although occurring in both dolomite members, the spherules are more abundant in the lower dolomite where these features are generally concentrated along some bedding surfaces.

Most spherules are composed of chalcedony; some consist of megacrystine or quartzine and lutecite (Fig. 4). Chalcedony and megacrystine spherules are cavity fillings in the dolomite and are similar to birdseye

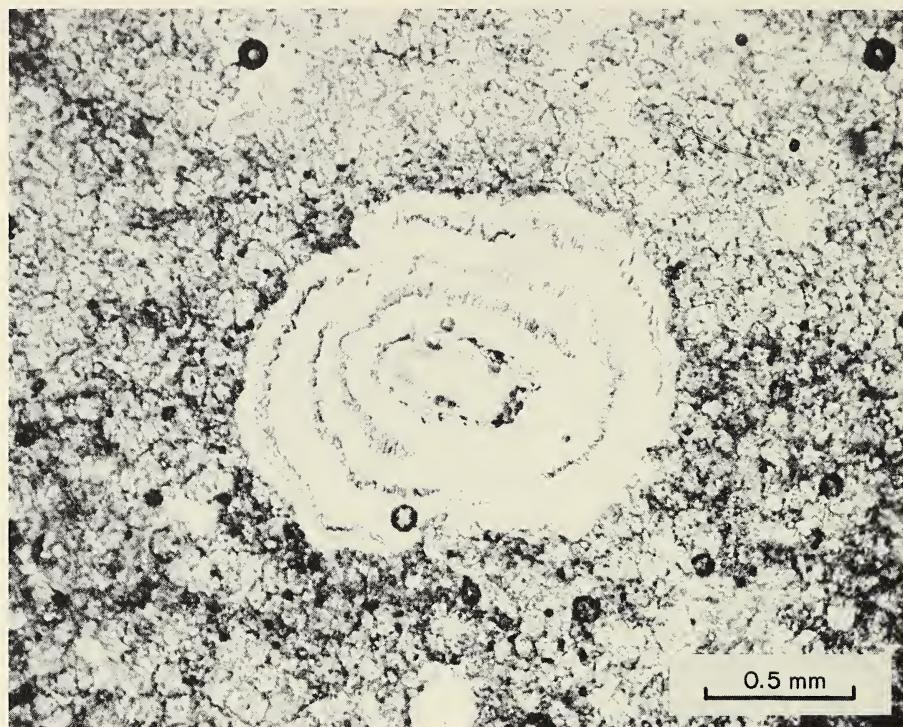


Figure 5. Photomicrograph of chert spherule in lower dolomite member showing well-defined iron oxide stained growth rings. Plane polarized light.

structures described by Folk (1973). Partial to total stages of cavity fillings were observed in thin sections. An empty or partly filled cavity may be less than 5.0 mm away from a completely filled cavity, thus showing extreme localization or selectivity of the chertification. No evidence was observed, however, to suggest that silica precipitation was selective of certain cavities because of pre-existing chemical or mineralogical conditions.

Some quartzine spherules appear to be cavity fillings, but others may have formed by replacing evaporite minerals. Folk (1972) described characteristics of "length-slow chalcedony" replacement of evaporite minerals, and marked similarities between his descriptions and the Alibates quartzine spherules are evident. A few spherules have shapes that are possible "ghosts" of gypsum or anhydrite crystals. Sulfate mineral replacement is suggested also by fibrous textures in the chert. Although no sulfate microlites are present in the quartzine, these possible relic gypsum textures are similar to those occurring in Permian

beds on Bear Island, Svalbard near Spitsbergen. Siedlecka (1972) described and illustrated scattered spherules (1-3 mm) of length-slow chalcedony that displayed the relic sulfate fibrous texture.

The random distribution of length-slow quartzine spherules in the laminated dolomite is similar to anhydrite crystals scattered throughout dolomite beds in a modern sabkha environment, as described by Wood & Wolfe (1969). They observed that poikilotopic anhydrite is common in lagoonal dolomite sediments, but they suggested that anhydrite did not form until after the dolomite was lithified. The described lithologic textures are identical to those of the dolomite and chert of the Alibates, and, although no evaporite minerals were found in Alibates outcrops in this study, much of the Alibates in the subsurface is gypsum and anhydrite (Presley 1987). Apparently only the mineralogy has changed; quartzine and luteelite have replaced the anhydrite.

Concentric growth rings similar to those described by King & Merriam (1969) occur in some chalcedony and quartzine spherules and are commonly accentuated by iron oxide staining (Fig. 5). Multiple generations of silica precipitation are suggested by these rings and by a few cavities filled with both chalcedony and quartzine. Some cavities show successive layers of chalcedony, quartzine, and chalcedony or megaquartz. This alternation of chert types suggests changes in the chemical environment during the stages of cavity filling. Because quartzine can form in a sulfate-rich environment (Folk 1972; 1974), quartzine interlayered with chalcedony in the cavity fillings may imply chemical changes in the interstitial waters during precipitation.

Many spherules have inclusions of finely crystalline or very finely crystalline dolomite. These carbonate microlites in the chert are generally near the quartz/carbonate boundary and appear to be crystals that were trapped in the silica precipitate. Opaque minerals, mostly iron and manganese oxides, and trace quantities of mica and clay are other impurities in the chert spherules.

Irregular chert masses.—Irregular masses of chert occur sporadically in both dolomite members but are more abundant in the upper part of the lower dolomite. These masses are not localized geographically and occur in most Alibates outcrops. There appears to be no predominant size or shape of the masses. Sizes range from a few millimeters to a few meters, and characteristic shapes include spherical nodules, elongate pods, and lenticular stingers. Nodular and podlike masses are best exposed in the Millican quarries on the Kritser Ranch approximately 32

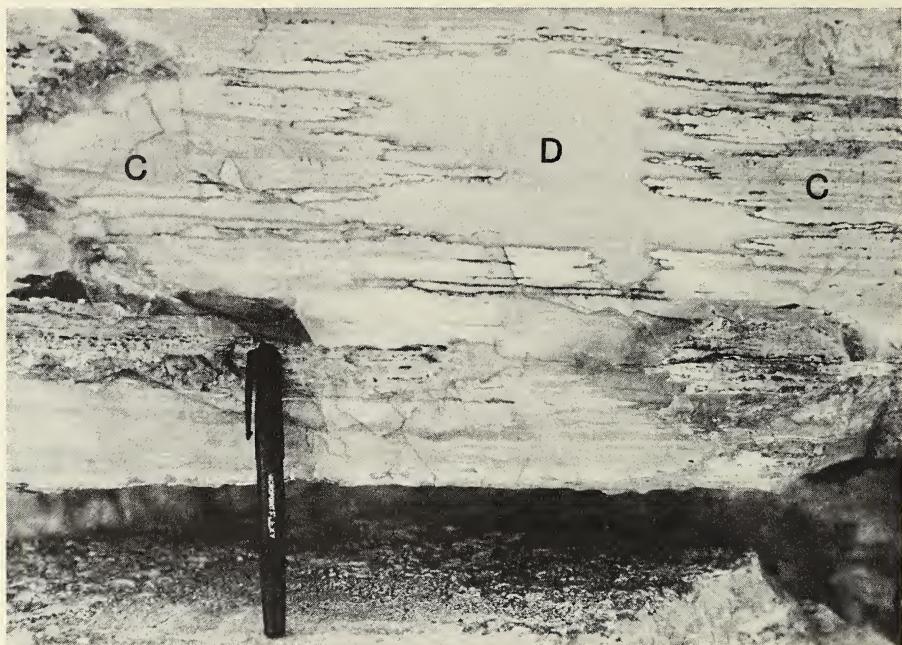


Figure 6. Photograph of lower dolomite member showing interfingering of dolomite (D) and chert (C), northern Kritser Ranch. Porous, chicken wire-type chert shown behind pen and at right margin. Length of pen is 13.5 cm.

km north of Amarillo. Locally, the chert masses average 50 cm in longest dimension and are generally elongated normal to bedding surfaces and parallel to near-vertical fractures in the rock. Spectacular exposures of interfingering bodies of dolomite and chert occur near the head of Hackberry Canyon on the Kritser Ranch (Fig. 6) where colorful stringers of chert project from fractures into the dolomite body along bedding surfaces. Lenticular embayments and stringers are most common in the Alibates Flint Quarries National Monument and vicinity.

The chert masses all are similar in composition and internal structure. In outcrop, the chert/dolomite contact appears to be sharp, and iron oxide staining in the chert readily delineates the contact on fresh surfaces. The dark, resistant chert is most obvious on weathered surfaces. Lamination of the dolomite is continuous into the chert and is more distinctive as bands in the chert because of iron oxide coloration. In addition, unreplaceable islands of laminated dolomite as large as 10 cm have been found "floating" in many chert masses. At a few places, dolomite breccia has been preserved by the chert. Banks (1990:129: 144:pl. 10E) also reported silicified breccia from Alibates Dolomite near Plum Creek on the Weymouth Ranch, Moore County, Texas.



Figure 7. Photograph of hand specimen showing chertified dolomite breccia, upper dolomite member, Alibates Flint Quarries National Monument. Diameter of coin is 21 mm.

Thin sections of irregular chert masses show that most of the chert is fine- to coarse-grained microcrystalline quartz with minor amounts of chalcedony and megaquartz. The chertification process is revealed under the microscope. Microcrystalline quartz commonly occurs as an anastomosing network of stringers that invades the dolomite along porous laminae and fractures. Chert fronts of microcrystalline quartz form along the porous zones and project veinlets outward to infiltrate the dolomite. As chertification proceeds, the chert veinlets surround and isolate individual dolomite crystals thus forming a "chert-permeated" dolomite. The final stage of chertification is complete replacement of the dolomite. The entire replacement by chert or the complete transition from dolomite to chert may be displayed in a distance of less than 1.0 cm.

Massive sheet chert.—Complete replacement of a dolomite outcrop by chert occurs at two known locations: the Alibates Flint Quarries National Monument and the Devil's Canyon-Cactus Flats vicinity, about 5 km west of the Monument. At these locations, the upper dolomite has been completely replaced by chert, thereby forming large, massive, tabular sheets that range in thickness from 0.2 to 0.6 m and extend

laterally for more than 1,000 m along the outcrop. Only the upper dolomite member has been completely replaced in these two areas; the lower dolomite member contains minor amounts of chert in the common forms of spherules and nodular masses as in all other Alibates outcrops examined. Although no "remnant" dolomite has been found in the massive sheets, the common dolomite features are well preserved in the chert. As in irregular masses described above, dolomite laminae are preserved in the chert as alternating bands of red, gray, brown and several other colors. The wide variation in color of the chert probably reflects the presence of minor amounts of aluminum, iron, and manganese (Bowers 1975). Chertified dolomite breccias are usually preserved as white fragments in a red to brown matrix (Fig. 7).

In thin section, massive chert is predominantly fine-grained microcrystalline quartz. Most laminae appear as bands defined by alternating color or impurity content rather than a change of grain size or other grain characteristics. Alternating bands of very fine- and fine-grained quartz occur only in a few thin sections of massive chert rocks. These bands average 0.25 mm thick and are wavy or wispy. Iron oxide staining and trace concentrations of opaque minerals change from band to band. At chert/dolomite contacts, bands in the chert are continuous with laminae in the dolomite. Minor quantities of chalcedony and megaquartz appear as patches within the microcrystalline quartz. These patches may have been the last remaining dolomite "islands" as chertification proceeded and thereby suggest later stages of silica precipitation. The patches also represent chert spherules that were in the dolomite prior to the massive replacement.

Sedimentary breccia occurs within the massive sheets. The breccia formed either by collapse during solution of subjacent evaporite, rip-up of algal-mat layers during storm events, or a combination of these two processes. The chertified breccia appears as fine-grained microcrystalline quartz in thin section. All breccia features have been replaced uniformly by microcrystalline quartz. The rock fragments, laminae within fragments, and breccia cement are differentiated only by coloration and impurity content rather than by grain size or other grain characteristics. These petrographic characteristics are identical to those described above for lamination and indicate complete replacement of the original dolomite breccia. Replacement took place after brecciation. There is no evidence to suggest that the laminated dolomite was first replaced by chert, brecciated, and then cemented by chert or other material that was subsequently replaced by chert. At a few places,

however, the massive chert has been fractured and the fractures subsequently lined or filled with more chert. In thin section, these fracture fillings are megaquartz or chalcedony, or both.

REPLACEMENT ORIGIN

Evidence and controlling factors.—Klein & Walker (1995) observed that silica polymorph replacements of carbonate minerals in marine and meteoric waters is a "common early diagenetic feature of sedimentary rocks." According to Maliva & Siever (1989), outlines of "carbonate precursors" in chert bodies clearly document that most nodular chert is a replacement of carbonate strata or sediments. Evidence from this study for a replacement origin for most of the Alibates chert can be summarized as follows:

1. Chert stringers and chert embayments into the dolomite.
2. Relic laminae in the chert that pass from dolomite into chert.
3. Sedimentary dolomite breccia preserved as chert.
4. Dolomite islands "floating" in a chert matrix.
5. Rhombic crystal "ghosts" and fibrous textures in chert that may represent relic evaporite minerals.

The evidence for massive replacement in the upper dolomite is basically the same as for the irregular masses and spherules. However, the controlling factors for such complete, yet localized, replacement are not obvious. Occurrences of chert spherules and sporadic, tear-shaped masses are easily related to chertification along joints, faults, and porous zones in the dolomite, but field observations made during this study coupled with the evaluation of published geologic maps and air photos of the Monument area show no obvious structural controls for localizing the massive chert.

New regional studies of the Texas and Oklahoma panhandles may lead to recognition of controlling factors. Cooley (1984) and Dolliver (1984) identified lineaments in the region using Landsat imagery. Both areas of massive replacement appear to be along a common lineament, which may reflect some structural control. In a study of the Anadarko basin in Oklahoma, Nielson & Stern (1985) used side-looking radar images to identify regional structural trends that project into the Alibates study area. They presented evidence for reactivation of Pennsylvanian faults during Permian or more recent time, or both. This reactivation of

regional structural features may have been a controlling factor for the massive replacement of the upper dolomite member.

It appears from chert/dolomite spatial relationships (proximity to fractures and larger abundance in upper dolomite) described earlier that chertification probably proceeded downward from the top of the Alibates. Because all overlying rocks have been removed by erosion, any stratigraphic or lithologic controlling factors are totally speculative. However, it is possible that the upper dolomite acted as a chemically reactive zone that resulted in the precipitation of silica from descending solutions. Locally, this zone failed to remove all the silica from aqueous solutions, and the silica leaked into the lower dolomite. No evidence to suggest topographic controls for localization of the chert was observed.

Sources of silica.—The sources of silica for Alibates chert are not known. It is possible that the silica was derived from the host rock during early diagenesis late in the Permian Period, however, this is difficult to ascertain because of the extensive dolomitization of the rock body. The only sources of silica observed within the Alibates are detrital sand, silt, and clay in the dolomite and middle red beds. Silicate detritus in the dolomite is a possible, but extremely limited, source for the chert spherules; no biogenic sources of silica in the Alibates are known. If primary biogenic sources such as spicules and radiolarians existed, the biological elements have been obliterated by dolomitization and other processes. Some chert in the lower dolomite may have been derived from the middle red-bed member, but no evidence was found to suggest leaching of silica from the mudstone. On the contrary, incipient quartz overgrowths were observed on some sand grains from the middle red-bed member.

No local source of silica within the Alibates, past or present, could volumetrically account for the total replacement of the upper dolomite member at the Alibates Flint Quarries National Monument and at Cactus Flats. It is not probable that any known natural process could concentrate a primary Alibates silica source into such a localized body, preserve the sedimentary features of the dolomite, and not affect the overlying and underlying strata. The underlying red-bed and lower dolomite members are no different at these massive-sheet chert localities than the units are at any other Alibates exposure, and only remnants of Ogallala conglomerate overlie the chert sheets. Although it is possible that slight permeability differences within the Alibates could have caused localization of silica derived from below, evidence suggests that the source of silica was stratigraphically above the Alibates. Petrographic

examination of underlying red beds revealed no chemical alteration of quartz, feldspar, or mica grains. However, quartz overgrowths do occur in overlying redbeds. In addition, multiple generations of chert as seen in thin section may also suggest multiple sources of silica.

The Alibates is known to be overlain by a present maximum thickness of 76 meters of Triassic rocks in the western part of the study area (Barnes 1969), and other studies (King & Merriam 1969 and others) suggest that Jurassic and Cretaceous rocks also may have once covered the Alibates in the Texas Panhandle. The Triassic rocks are predominantly terrigenous and contain chert and petrified logs (Barnes 1969). Silica may have been derived from bentonite, tuffaceous rock, and silicate minerals. Extensive opalization at some places in the Miocene-Pliocene Ogallala Formation (Norton 1939; Frye & Leonard 1959; Harlow, pers. comm.) indicates more recent possible sources of silica.

Analyses of groundwater from the Ogallala aquifer throughout the Great Plains region show above-normal concentrations of silica in solution (Swanberg & Morgan 1979). Although reliable chemical analyses of groundwater from the panhandles of Texas and Oklahoma are few, Swanberg (pers. comm.) feels that the Ogallala aquifer is a rich source of silica throughout the region. Because heat-flow values do not suggest a large regional thermal anomaly as a cause of the high-silica concentrations and because the water comes from continental deposits, the high values probably reflect solutions saturated with amorphous silica. According to Swanberg (pers. comm.), the source of silica is most likely Pliocene to Holocene ash from western volcanic centers such as the Jemez Mountains in New Mexico and Yellowstone in Wyoming. However, the small amounts of alkali, aluminum, and titanium oxides present in Alibates dolomite and chert (Table 2) precludes a major volcanic source (Maliva & Siever 1988:423). Indigenous plant remains (seeds, roots, stems) or wind-deposited opal phytoliths could also have been a source of silica cement in the Ogallala.

Chertification models.—Several models have been proposed for the origin of nodular chert. According to these models, chertification can result from the oxidation of organic matter, oxidation of hydrogen sulfide, crystallization pressure applied to silica-carbonate boundaries during crystal growth of quartz and opal-CT, and supersaturated quartz and opal-CT and undersaturated calcite occurring simultaneously in pore waters along part of a coastal mixing zone. These models are discussed in detail by Maliva & Siever (1989). The origin of chert spherules in

the upper and lower dolomite members could be explained by the mixing-zone model proposed by Knauth (1979). As noted earlier, most of the chert spherules occur along bedding surfaces. This is in agreement with Knauth's model for the origin of chert in limestone in which the chert formed in a mixing zone of meteoric water and sea water. The resulting zone of chertification is dependent on the porosity and permeability of the sediments. Quartzine and lutecite spherules from the Alibates are probable replacements of sparsely disseminated evaporite minerals, and the spherules displaying growth rings suggest seasonal(?) fluctuations of pH in the mixing zone of the model or local changes in water chemistry because of mineral reactions. However, Dawson (pers. comm.) stated that the Knauth model, which has never been demonstrated to work in nature, is "based on thermodynamic calculations, whereas, chertification (like most other diagenetic processes) is kinetically controlled."

Percolation/concentration model.—The nature of the irregular chert masses suggests a different origin than that for the chert spherules. Therefore, a percolation/concentration model is proposed to explain the origin of these bodies. The masses have formed by chertification along inclined fracture zones and permeable horizons that extend laterally into the dolomite body. Concentrated in the upper parts of both dolomite members, chertification has proceeded generally from the top downward into the dolomite. At places on the Kritser Ranch, especially near the Millican quarries where the upper dolomite is absent, large blocks of the lower dolomite member have slumped and created funnel-shaped openings between blocks which, in outcrop, are as much as two m wide across the top. These funnel-shaped openings, together with many smaller fractures in the dolomite, are filled with younger grayish orange-pink, calcitic, arenaceous material (Ogallala?). Angular chert, nucleated within the fissure fills, spread outward into the surrounding dolomite. No chert spherules were found "trapped" in irregular masses, but chertification of the masses appears to be much younger than the spherules. The greasy luster and subtranslucent appearance of some chert along fractures in the Alibates suggests that chertification is still taking place today (Fig. 8). McBride (1988:865) noted that the chertification of carbonate clasts from Tertiary conglomerate in west Texas near Big Bend National Park "must have been fairly rapid, because it is unlikely that the proper hydrologic and chemical conditions prevailed for more than a few million years." Hattori et al. (1996:169) also reported that chertification can occur rapidly on surface rocks.



Figure 8. Photograph showing dark incipient chertification (C) along steeply dipping fractures and bedding surfaces at Hackberry Canyon, northern Kritser Ranch. Head of rock hammer (center) marks intersection of large fracture and bedding surface.

The hypothesis of silica entering the Alibates from overlying strata concurs with an earlier interpretation proposed for chertification in another part of the Great Plains (Banks 1984:74). Norton (1939) described similar chert occurrences in the Day Creek Dolomite in Kansas and concluded that "The preponderance of evidence favors the theory of replacement by silica from percolating ground water from overlying strata, the commonest source being the sandy conglomerate of the Tertiary Ogallala 'mortar beds.'"

Banks (1990:96) reported that multicolored chert occurs in the Smoky Hill Member of the Niobrara Formation. Although the member crops out in four western states, the chert occurs only at places where Ogallala directly overlies Smoky Hill Chalk. He remarked that chert in the unit resulted from "silica replacement of chalk" in the upper part of the rock body.

Walker (1960; 1962) proposed that chert-carbonate replacement is a reversible process. Calcite replaces silica (primarily detrital quartz), and silica is then transported in solution and reprecipitated nearby. Walker (1962) stated that the probable cause of such replacement reversals is

fluctuation of pH in interstitial water. Conversely, experimental work by Klein & Walker (1995) indicated that the uptake of silica onto calcite surfaces in artificial seawater was irreversible and "strongly time and pH dependent." Brown (1956) and Reeves (1970) documented the formation of caliche in the Ogallala Formation in the study area. According to Reeves (1970), one result of the calichification process is oversaturation of solutions with respect to silica because of high pH. Knauth (1979) and several others have discussed the relationship of pH and silica precipitation. More recently, Williams & Crerar (1985) have shown that a carbonate chemical environment enhances silica (opal-CT) precipitation. Furthermore, the presence of magnesium (esp. Mg(OH)₂) dramatically affects silica precipitation. Bowers (1975) suggested that it is possible for high-pH, silica-rich, groundwater from the overlying strata to percolate a relatively short distance downward into the Alibates Dolomite. The change in lithology from the terrigenous sandstone, red beds, and conglomerate to dolomite would cause a lowering of pH in the descending solutions and, together with the increase of magnesium in the dolomite, promote precipitation of silica in the dolomite.

McBride (1988:862) reported that Cretaceous carbonate pebbles and cobbles incorporated in Tertiary fluvial rocks from the Big Bend National Park area of west Texas have thin (1-5 mm) chert rinds that were formed by groundwater after deposition. He stated (p. 865) that these carbonate clasts "were replaced by opal-CT on a volume-for-volume basis."

In order to investigate further the silica diagenesis, representative chert samples from the Alibates and the overlying Ogallala were analyzed for oxygen isotopes. Ten hand samples were collected and each sample was broken in half to make duplicate sample sets. Sample 1 is petrified wood from the Ogallala less than 50 cm above the Alibates/Ogallala contact in an outcrop near Clarendon, Donley County. Sample 2 is chertified caliche from the Ogallala and is common throughout the study area. The remaining eight samples are Alibates chert from the Kritser Ranch, Cactus Flats, and the Monument area.

Results of the analyses are given in Table 3. The data show that the isotopic ratios for two nearly pure (oxygen yield > 97.5%) Ogallala chert samples are 29.7 and 31.1. Isotope ratios of relatively pure (oxygen yield > 97.0%) Alibates chert range from 28.3 to 32.2 with the highest ratio occurring at the Alibates Flint Quarries National Monument. Average ratio for Ogallala chert is 30.4 and average ratio for Alibates chert is 30.0. The high (heavy) $\delta^{18}\text{O}$ values in these Alibates

Table 3. Oxygen-isotope ratios of selected chert samples from the Alibates and Ogallala formations.

Sample Number ^A	Yield (%)	$\delta^{18}\text{O}$ (SMOW ^B)	Sample Number ^A	Yield (%)	$\delta^{18}\text{O}$ (SMOW ^B)
Ogallala			Alibates		
1. (D-1-8)	97.6	29.7	3. (D-1-6A)	84.4	29.0
2. (HS-1-1)	98.4	<u>31.1</u>	4. (P-2B-3)	85.2	27.1
Average		30.4	5. (P-3-13)	99.7	29.7
			6. (P-4-7)	98.5	30.7
			7. (P-9-C)*	97.0	28.3
			8. (P-9-F1)*	99.2	30.7
			9. (P-9A-F)*	99.2	32.2
			10. (P-10-3)	96.2	<u>32.7</u>
			Average		30.0

^A Sample designation indicates county, (D-Donley; HS-Hutchinson; P-Potter), measured section and unit; for detailed description refer to Bowers (1975).

^B Standard mean ocean water.

* Chert sample from Alibates Flint Quarries National Monument.

and Ogallala samples suggest that the chert crystallized in relatively cold, oxygen-enriched meteoric waters.

Unfortunately, the data are not definitive. The range of ratios is larger than anticipated, and it is not known how much of this difference is attributable to natural variation within a given type of sample. If most of the discrepancy is caused by natural variation and the range of values that may be obtained from a single hand sample of chert is large, it could be concluded that such a large range of values further substantiates the hypothesis of multiple sources and episodes of silica precipitation for the Alibates chert. The value and reliability of the oxygen-isotope analyses as a tool could be increased substantially by developing a much larger data base for Permian chert.

The overlap of values for both Alibates and Ogallala chert probably indicates that the composition and temperature of solutions were similar during chert formation. A comparison of these data with a temperature scale applied to isotope ratios from the late Paleozoic Arkansas Novaculite (Jones & Knauth 1979) suggests that isotopic temperatures ranged from approximately 21.0° to 37.0°C during crystallization of the Alibates chert. Most workers today believe that chert takes a relatively short time to form (i.e. McBride 1988; Klein & Walter 1995); the large temperature range indicated by the analyses of this study suggests that it formed during an interval of time characterized by major climatic changes. This interpretation is certainly questionable in light of all other evidence presented here that suggests multiple stages of chertification

throughout the history of the Alibates. Some of the Alibates samples have delta-values that are similar to ratios reported both for older (Jones & Knauth 1979) and younger chert (Land 1977). Knauth (pers. comm.) remarked that "The similarity of isotopic composition of these Permian cherts to younger cherts suggests that ^{18}O -enriched evaporite waters were probably not involved in the silicification of the evaporite minerals. These were probably fresh waters super-saturated with respect to silica which were dissolving the evaporites."

CONCLUSIONS

The physical and petrographic characteristics of the Alibates chert document its origin by replacement; the source of the silica, however, remains speculative. The nature of the chert/dolomite relationships as studied in outcrop, plus the oxygen isotope and Ogallala water chemistry data, support the following conclusions:

1. Most of the silica came from sources outside of the Alibates Dolomite.
2. The sources of silica probably were stratigraphically above the Alibates Dolomite.
3. Most of the chert was localized in the dolomite by percolation along fractures and porous/permeable zones.

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GENERAL NOTES

TWO MOUTHLESS CYPRINIFORM FISHES FROM LOUISIANA

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Reduction of mouth parts resulting in permanent closure of the buccal cavity and impaired feeding in vertebrates is termed oral atresia and ranges in severity from abnormally small mouth openings to complete absence of an opening (Menzel 1974). Although comparatively rare, microstomatous and astomatous fishes have been observed for over a century (Leidy 1875; Dawson & Heal 1976). This condition is attributed to congenital defects in development and to recovery from traumatic head injury (Leidy 1875; Menzel 1974).

Ichthyological holdings of the Northeast Louisiana University Museum of Zoology (NLU) are extensive, comprised of 71,744 lots, 1,601,894 specimens, and over 1654 species (Douglas 1994; Poss & Collette 1995). They include only two astomatous fishes, reported herein for the first time; a smallmouth buffalo, *Ictiobus bubalus* and a common carp, *Cyprinus carpio*. Both individuals were collected from the Ouachita River drainage by local fishermen using gill nets. Morphology of anomalous fishes (Figs. 1A, 1B) was conspicuously different from that of normal, comparably-sized individuals (Figs. 1C, 1D).

Ictiobus bubalus (Rafinesque)
smallmouth buffalo

Material examined.—Tensas River, Madison Parish, Louisiana, 9 May 1967, one specimen (NLU 6240), (Fig. 1A).

Variation.—The astomatous buffalo, measures 408 mm total length (TL), 314 mm standard length (SL) and weighs 794 grams. Lips, tongue and mouth are absent, replaced with a tight integument covering the buccal cavity. Radiography indicates absence of left lacrimal, left 1st, 2nd, 3rd subocular, dentary, premaxillary, and maxillary bones. Although species-level identification necessitates examination of mouth-parts, corporal characteristics of this specimen are consistent with those of smallmouth buffalo: i.e., highly arched back, strongly keeled predorsal region, straight ventral contour (Douglas, 1974). Age, estimated

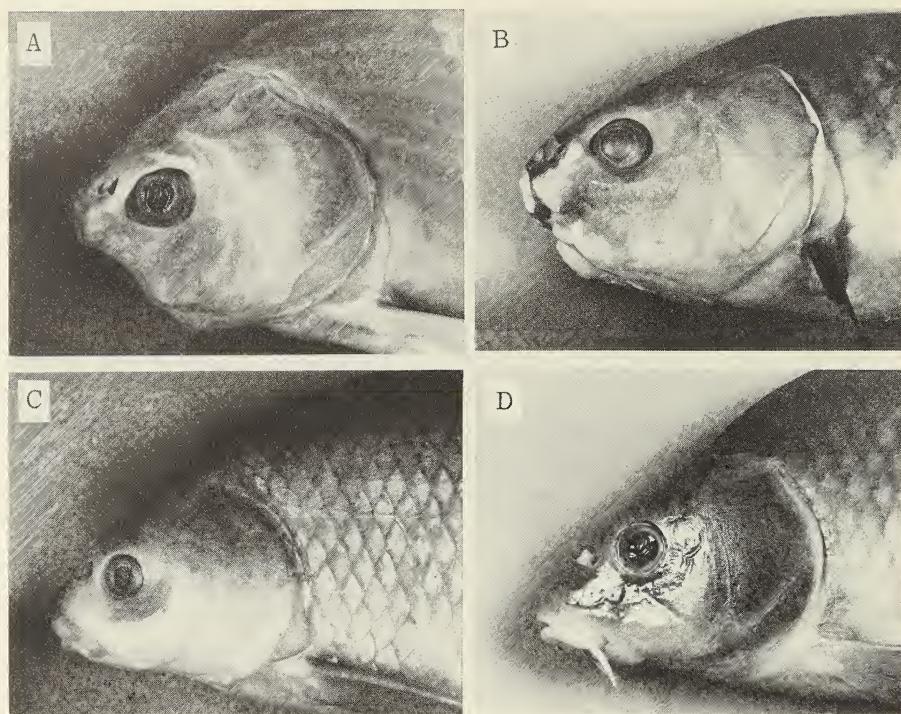


Figure 1. Cypriniform fishes from the Ouachita River: A. astomatous smallmouth buffalo (408 mm TL); B. astomatous common carp (351 mm TL); C. typical smallmouth buffalo (421 mm TL); D. typical common carp (318 mm TL).

from annuli on scales, is placed at four years (or more). Digestive tract of the mouthless buffalo contained small quantities of detritus.

Remarks.—The mouthless buffalo exhibits below-average robustness. Smaller specimens of normal buffalo (381-405 mm TL) typically weigh more than the astomatous specimen (794-848 g) and may weigh in excess of 1000 g (Carlander 1969). Condition factor of the astomatous specimen ($K_{TL} = 1.17$) is lower than values previously reported ($K_{TL} = 1.29-1.53$). Length, however, is intermediate for reported values of four year old specimens (244-488 mm TL). Prior to this report only two other buffalo with oral atresia were documented in scientific literature: a microstomatous specimen, approximately 380 mm TL, from the Ouachita River, Arkansas (Leidy 1875) and an astomatous specimen, 536 mm TL, from Moon Lake, Mississippi (Fuller 1951). Two other atresic buffalo are reported from the Ouachita River drainage, Louisiana, but precise locality data and disposition of specimens are unknown: an astomous specimen was collected from the Ouachita River

in 1985 and observed alive by the junior author, and a microstomatous individual was netted by a fisherman from Bayou Bartholomew (Anonymous 1989).

Cyprinus caprio Linnaeus
common carp

Material examined.—Lake Providence, East Carroll Parish, Louisiana, 7 September 1984, one specimen (NLU 56744) (Fig. 1B).

Variation.—The astomatous common carp, 351 mm TL, 256 mm SL, 340.2 grams, also has a tight integument covering the buccal cavity (Fig. 1B). Radiography indicates absence of premaxillaries, maxillaries, and most of each dentary. Based on scale annuli, the age of the specimen is estimated to be three years (or more). Digestive tract was empty.

Remarks.—The mouthless carp is emaciated. Its weight is approximately half that of normal specimens of comparable size (613-690 g); its condition factor ($K_{TL} = 1.48$) is substantially less than values documented from normal individuals ($K_{TL} = 2.37-2.92$). Length is intermediate for values of three year old specimens (114-630 mm TL) (Carlander 1969). Common carp with oral atresia are known from European waters, but only a single astomatous individual is reported from North America; that specimen is similar to NLU 56744 but lacks additional skull bones, nostril, and right eye (Menzel 1974).

DISCUSSION

Mouthless fishes probably obtain food by retaining particles on their gills and periodically swallowing accumulated material (Menzel 1974). This could be accomplished actively with radical changes in behavior (e.g., swimming backwards with opercula flared). More likely, it occurs by passive retention of food. Since there is no functional mouth, intake and outflow of water must both take place through the gill aperture, resulting in a continuous cycle of flushing and backflushing across the gills, with concurrent ingestion of available plankton and detritus.

Asymmetrical deformities in the buffalo and incomplete dentary bones in the carp suggest that both specimens suffered traumatic head injuries, but recovered sufficiently to heal, and modified respiration to accommodate absence of a mouth. Following their respective injuries, however,

the buffalo was probably able to feed more successfully than the carp, which is supported by observations of gut contents. Smallmouth buffalo, even as adults, feed on zooplankton, possibly straining them with their 30-40 gill rakers (Carlander 1969). Mouthless individuals, then, may suffer impaired feeding, and lowered robustness as a result, but could survive indefinitely at a lower rate of feeding (Bailey 1951). Adult carp, in contrast, are benthivore-herbivores with only 21-27 gill rakers, and may be unable to effectively filter food from the water (Carlander 1969). A mouthless individual would starve, surviving only off the reserves in its own tissues, its lack of robustness indicative of time elapsed since injury (Menzel 1974).

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NOTES ON THREE SPECIES OF SMALL MAMMALS FROM THE BIG BEND REGION OF TEXAS

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Field work conducted in Big Bend Ranch State Park, Presidio and Brewster counties, Texas, during 1994 and 1995 yielded noteworthy specimens of two species of small mammals. An additional notable specimen of a third species from the Big Bend region was located in the Collection of Recent Mammals of The Museum, Texas Tech University. The significance of these specimens is detailed in the following accounts. Voucher specimens (TTU) consisting of skins and skulls and frozen tissues (TK) are deposited with the Collection of Recent Mammals in the Natural Science Research Laboratory of the Museum of Texas Tech University.

Notiosorex crawfordi crawfordi (Coues) Desert Shrew

Notiosorex crawfordi has been recorded from a variety of habitats within the western two-thirds of Texas (Jones & Jones 1992; Davis & Schmidly 1994). It is thought to exist throughout the Trans-Pecos region, but specimens from this area have been reported only from desert-scrub habitats of El Paso, Jeff Davis, and Brewster counties (Schmidly 1977). Baker (1956:169) stated that *N. crawfordi* probably occurred "in suitable places throughout the Chihuahuan Desert Shrub Vegetation type" in nearby Coahuila, Mexico, whereas Anderson (1972) suggested that desert shrews ranged probably in most parts of Chihuahua, Mexico, from the lowest, hottest desert up to at least 6900 feet. Incidentally, the records of *Notiosorex* from Coahuila and Chihuahua were based on materials obtained from owl pellets; no desert shrews were trapped (Baker 1956; Anderson 1972).

A specimen of *N. crawfordi* from Presidio County was found in the Collection of Recent Mammals of The Museum, Texas Tech University (TTU 31606). This individual of unknown sex was taken from a site along U.S. Hwy. 90, 3.1 mi. E of the junction of Texas Hwy. 17 in Marfa on 15 September 1973. According to field notes also deposited at The Museum, it was acquired from a "short grass area." This report represents the first published record of the desert shrew from Presidio

County. In addition, this is the only account of *N. crawfordi* from the Trans-Pecos region occurring in habitat other than desert scrub.

Myotis velifer incanus (J. A. Allen)
Cave Myotis

The cave myotis occurs in the western two-thirds of Texas. This bat is a year-round resident of the Panhandle and the Edwards Plateau of Texas, where it hibernates in caves over the winter (Schmidly 1991). It is the most broadly distributed species of *Myotis* in the Trans-Pecos region (Schmidly 1977), but winter records have not been documented (Schmidly 1977; 1991). In addition, winter records for the South Plains region of Texas are lacking (Schmidly 1991). Based on these data, Schmidly (1991) concluded that during the winter this species probably is restricted to the central and north-central areas of Texas.

A nongravid female *M. velifer* (TTU 67590) was collected on 26 February 1995 in Big Bend Ranch State Park, Presidio County (UTM coordinates 13 615559E 3268762N). This specimen represents the first winter record of the cave myotis from Trans-Pecos Texas. It was taken while flying over a small stream associated with riparian vegetation dominated by willow (*Salix* sp.), false willow (*Baccharis* sp.), cottonwood (*Populus* sp.), and oak (*Quercus* sp.). The stream is in the bottom of a canyon approximately 20 m in depth. Walls of the canyon are composed of steep cliffs with several small caves near the top. The acquisition of this specimen indicates that at least a portion of the Trans-Pecos population of *M. velifer* winters in the region. It is likely that the majority of individuals of *M. velifer* in this area migrate from the region to winter hibernacula, as is reported for members of populations from Arizona and California (Stager 1939; Barbour & Davis 1969). A few exceptional individuals apparently hibernate in local caves throughout the winter, occasionally taking flight only for short periods of time, as do individuals from the Panhandle (Schmidly 1977).

Sigmodon ochrognathus Bailey
Yellow-nosed Cotton Rat

In Texas, the yellow-nosed cotton rat is known only from the higher elevations in the southern Trans-Pecos region (Jones & Jones 1992). It has been characterized as an inhabitant of upland habitats in adjacent areas of Coahuila (Baker 1956) and Chihuahua, Mexico (Anderson 1972), as well as elsewhere throughout the disjunct range of this species

(Findley & Jones 1960; Baker 1969). In Trans-Pecos Texas, *S. ochrognathus* occurs in the Chisos Mountains of Brewster County and the Davis Mountains of Jeff Davis and Brewster counties at elevations above 5000 feet. In these areas, it is common in grassy, montane flats and upland grassland-woodland associations (Schmidly 1977). Also, a single specimen is known from the Sierra Vieja in northwestern Presidio County. This individual was acquired from a steep, rocky slope in grama-bluestem grass association at an elevation above 4500 feet (Blair & Miller 1949).

A single specimen of *S. ochrognathus* was collected in Presidio County during this study. The individual (TTU 68598, TK 48160), a pregnant female (4 embryos, crown-rump length 9 mm), was acquired on 5 August 1995 from a locality in Big Bend Ranch State Park (UTM coordinates 13 601619E 3260741N). It was taken from a lowland, seasonal stream bed near a permanent spring at an elevation of 4200 feet. The immediate vegetation is best described as riparian, dominated by deergrass (*Muhlenbergia* sp.) and false willow. The habitat adjacent to the stream bed is desert scrub on a rough, rocky substrate. This specimen represents the second yellow-nosed cotton rat reported from Presidio County, and the first taken in the Trans-Pecos region from habitat of this description in a non-montane area.

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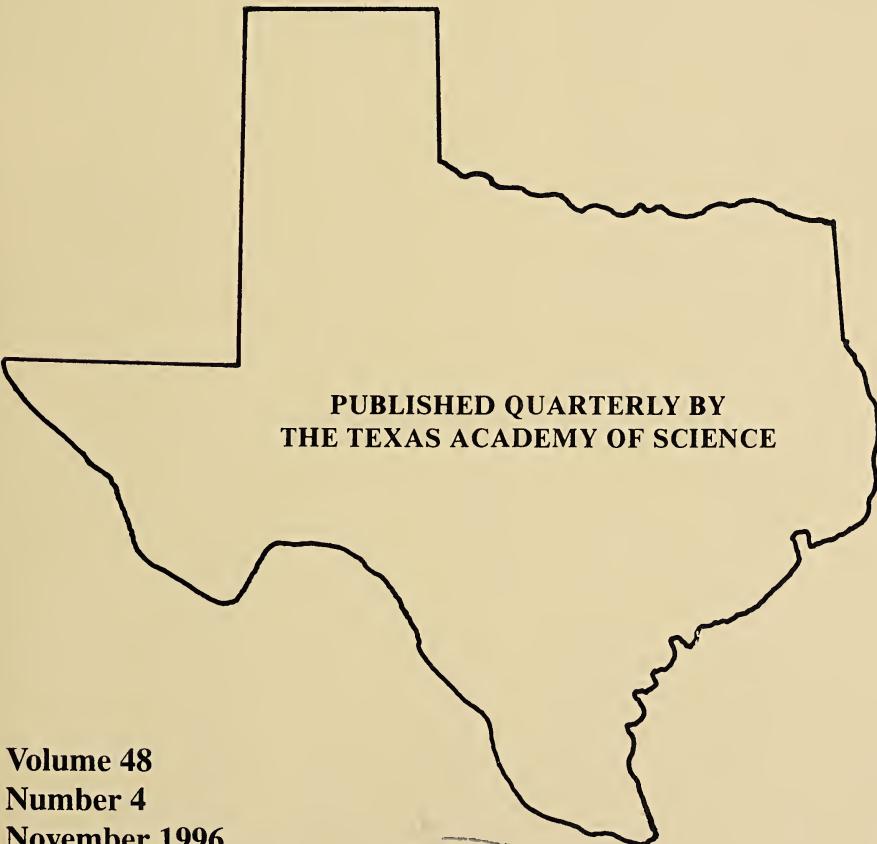
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HABITAT PREFERENCE OF LARGE PREDATORY AQUATIC INSECTS (MEGALOPTERA AND ODONATA) IN OZARK STREAMS OF ARKANSAS

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Abstract.—Megaloptera and odonata larvae were collected from the White and Illinois rivers and Clear Creek in northwest Arkansas from February 1991 through February 1992. Collections were made from both coarse woody debris (CWD) and benthic habitats. Megalopterans were collected in significantly greater densities from benthic habitats ($33 \pm 8/m^2$) than from coarse woody debris ($7 \pm 2/m^2$). There was no significant difference in odonate density between the two habitat types. Of the insects collected, the megalopterans *Corydalus cornutus* and *Sialis sp.*, and the odonate *Stylogomphus albistylus* had significantly greater densities in benthic habitats. No other species collected exhibited a significant preference for habitat type. *Corydalus cornutus* inhabiting wood exhibited a significant preference for wood that was well decayed and for wood with rough-textured bark.

Megalopteran and odonate larvae are predatory and feed on a wide variety of aquatic invertebrates (Evans & Neunzig 1984; Westfall 1984). Representatives of these orders occupy a variety of lentic and lotic aquatic habitats (Needham & Westfall 1955; Merritt & Cummins 1984). Benke et al. (1984) and Smock et al. (1985) collected megalopteran and odonate larvae in greater densities from submerged woody debris than from benthic habitats in blackwater streams of the southeastern United States. The reason for increased abundance on woody debris in these streams was related to the instability of the primarily sand substrate (Benke et al. 1984).

Although recent work relative to the utilization of wood debris has added to the knowledge of these habitats, many questions about wood utilization in different types of streams remain unanswered. The primary objectives of the present study were to determine if there were differences between benthic and coarse woody debris habitat selection, to determine the microhabitat factors that influenced coarse woody debris selection, and to determine differences in the seasonal densities of megalopteran and odonate larvae.

MATERIALS AND METHODS

Megalopteran and odonate larvae were collected monthly from the White River, Illinois River and Clear Creek from February 1991

Table 1. Methods for evaluating the degree of decay of woody debris, modified from Robison & Beschta (1990).

Decay Class	Bark	Twigs	Texture	Shape	Wood Color
I	Intact	Present	Intact	Round	Original
II	Beginning to loosen	Absent	Intact	Round	Original
III	Some loose bark remaining	Absent	Smooth, some surface abrasion	Round	Center original, edges dark
IV	Absent	Absent	Some holes and openings	Round to oval	Dark
V	Absent	Absent	Many holes and openings	Irregular	Dark

through February 1992. Three sites were sampled in each order of first through third orders of the White River, second through fourth orders of the Illinois River, and first through third orders of Clear Creek. Collections were made from coarse woody debris (CWD) and benthic habitats at all sampling sites. Coarse woody debris in this study included submerged snags, logs, chunks of wood resulting from the breakdown of larger snags and logs, and large branches; this follows the definitions of Harmon et al. (1986) and Robison & Beschta (1990).

Coarse woody debris samples were taken by placing a mesh bag (243 mm mesh size) over the wood so that no insects could escape as the wood was removed from the water, cutting the wood with a bow saw if necessary, and removing it from the water. Samples of CWD were taken in quantities sufficient to equal approximately $1.5 \text{ m}^2/\text{site/month}$. Visible insects were removed from the log and mesh bag at streamside and preserved in 70% ethanol. Logs subsequently were washed in a bucket to remove any additional insects, which were sorted by pouring the water through a standard sieve series then picked from an enamel pan. Each piece of CWD was evaluated, and placed into one of five categories designating its degree of decay (Table 1). Volumetric measurements of biofilm also were taken from each piece of CWD. Sampling was done by scraping all the biofilm from three 5 cm^2 areas and measuring its volume in milliliters, by water displacement in a 10 ml graduated cylinder. Mean volumes of biofilm per piece of CWD were then converted to ml/cm^2 . Categories of biofilm density were: light, less than $0.2 \text{ ml}/\text{cm}^2$; moderate, between $0.2 \text{ ml}/\text{cm}^2$ and $0.8 \text{ ml}/\text{cm}^2$; heavy, greater than $0.8 \text{ ml}/\text{cm}^2$. Biofilm included any plant or animal material growing on the CWD (Hax & Golladay 1993). Wood was then placed

in a five-gallon bucket to dry for five days and any remaining insects were collected as they left the drying wood. Insects were then identified and counted. The surface area of each piece of CWD was calculated from a conversion factor derived from the weight of plastic food wrap used to cover them (Doeg & Lake 1981; O'Connor 1991). Abundances of insects per square meter were calculated using this information.

In addition to CWD samples, 10 benthic samples were taken at each site during each month using a Surber sampler (243 mm mesh size). Samples were preserved in the field in 95% ethanol and later sorted, stored in 70% ethanol, identified, and counted in the laboratory. The surface area of each benthic sample was estimated from the measurements of substrate particle size at each site. Plastic wrap (Doeg & Lake 1981) was used to cover individual stones of different size classes, and surface area was calculated from a conversion factor of the weight of plastic wrap and total mass of each size class of stones (Shelly 1979; Reice 1980).

Two-way analyses of variance (*ANOVA*) were performed on larval densities to determine interactions among habitat type (benthic vs. CWD), and season (spring, summer, fall, winter). The Student-Newman-Keuls (SNK) multiple-range test was used post hoc to compare insect densities where significance was detected. Densities of insects are presented as number/m² ± the standard error (SE).

One-way *ANOVAs* were performed for individual species to determine if there was a significant difference in densities between CWD and benthic habitats. Two-way *ANOVAs* were conducted with the most abundant species collected from CWD, to determine if factors associated with the degree of decay, and/or the volume of biofilm growing on the CWD influenced their density. One-way *ANOVA* was used to determine if bark texture influenced density on CWD. The SNK multiple range test was used post hoc to compare insect density where significance was detected. The alpha level of significance for all statistical tests was 0.05.

RESULTS

Representatives of three species of megaloptera were collected from benthic and wood habitats combined. One-way *ANOVAs* revealed that the larvae of two species were collected in significantly greater densities from benthic habitats than from CWD. These were *Sialis* sp. ($F = 9.76$, $P = 0.005$) and *Corydalus cornutus* ($F = 7.71$, $P = 0.01$) (Table 2). Specimens of *Nigronia serricornis* were collected only from benthic habitats and in low densities.

Table 2. Mean annual density/m² (\pm standard error) of megalopteran larvae and odonate nymphs collected from benthic habitats and CWD (One-way ANOVA results, ** $P < 0.01$).

Taxon	Benthic	CWD
MEGALOPTERA		
<i>Sialis sp.</i>	34 \pm 8**	7 \pm 3
<i>Corydalus cornutus</i>	10 \pm 3**	1 \pm 1
ODONATA		
<i>Gomphus spp.</i>	25 \pm 9	25 \pm 16
<i>Stylogomphus albistylus</i>	2 \pm 2	0 \pm 0
<i>Boyeria vinoso</i>	7 \pm 2**	2 \pm 1
<i>Perithemis tenera</i>	0 \pm 0	2 \pm 2
<i>Amphiagrion sp.</i>	0 \pm 0	2 \pm 2
<i>Argia spp.</i>	2 \pm 1	3 \pm 1
<i>Chromagrion sp.</i>	6 \pm 1	13 \pm 7
	8 \pm 4	3 \pm 2

Megaloptera had significantly greater densities in benthic habitats than on CWD (SNK $P < 0.01$) (Table 2). Greatest seasonal densities of megalopterans were found during summer ($32.3 \pm 12.4/\text{m}^2$), followed by fall ($28.5 \pm 13.1/\text{m}^2$), winter ($11.6 \pm 3.3/\text{m}^2$), and spring ($10.4 \pm 5.3/\text{m}^2$); differences were not significant. There was no significant interaction between effects of habitat type and season on densities of megalopterans.

Two-way ANOVA comparing the densities of *Corydalus cornutus* collected from CWD among different degrees of decay and different volumes of biofilm showed significant results for decay class ($F = 7.56$, $P = 0.0005$), but not for biofilm volume ($F = 0.23$, $P = 0.79$). There was no significant interaction between the effects of decay and biofilm volume ($F = 0.24$, $P = 0.91$). Larvae of *C. cornutus* were found in significantly greater densities on wood in decay stage III and V. There was no significant difference between their densities from these two decay stages (SNK $P < 0.01$). One-way ANOVA showed that larvae of *C. cornutus* were more abundant on wood with rough-textured bark than on wood with smooth-textured bark ($F = 158.48$, $P = 0.0001$). Mean density on wood with rough bark was ($21.3 \pm 8.1/\text{m}^2$), compared with ($0.6 \pm 0.6/\text{m}^2$) on wood with smooth bark.

Representatives of six genera of odonata were collected from benthic and wood habitats combined (Table 2). The only species that was collected in significantly greater densities in one habitat over another was *Stylogomphus albistylus* which was more abundant in benthic habitats ($F = 9.06$, $P < 0.01$).

Two-way ANOVA showed no significant differences in densities of odonates between habitat types, or among seasons, and there was no

significant interaction between the effects of habitat type and season on odonate density.

DISCUSSION

Corydalus cornutus and *Sialis sp.* were the most commonly collected megalopterans, and both were significantly more abundant in benthic habitats. By contrast Benke et al. (1984) collected *C. cornutus* only from wood habitats. However, their findings for *Sialis sp.* which was collected only from benthic habitats, were similar to those from the present study. Smock et al. (1985) collected larvae of *C. cornutus* only from wood, and larvae of *Sialis sp.* in greater densities from benthic habitats. Differences in habitat specific abundances of *C. cornutus* between blackwater and Ozark streams probably are influenced substrate instability in blackwater streams, contrasted substrate stability in Ozark streams.

Specimens of *C. cornutus* collected from CWD exhibited a preference for wood in decay stages III and V. Wood in classes III and V probably provides a large food source for this predatory megalopteran, because these decay classes are the most heavily colonized by other insect species (Phillips 1993). Also, these decay classes provide interstitial spaces which allow *C. cornutus* larvae to better avoid predation. Similar reasons probably account for the higher density of *C. cornutus* on wood with rough bark.

There were no significant differences in densities of odonates between benthic habitats and CWD. Benke et al. (1984) found an assemblage of odonates of similar diversity in the Satilla River of Georgia, but representatives of many taxa occurred only on woody debris. They collected nymphs of *Argia* and *Boyeria vinosa* only from wood, whereas during this study these odonates were collected in similar densities from both habitat types. Smock (1988) also found *B. vinosa* only on snags. Smock et al. (1985) observed greatest densities of anisoptera and zygoptera on snags, followed by mud banks, and the stream bottom.

All odonate nymphs are predatory (Needham & Westfall 1955); thus associations with wood are facultative. The abundance of odonates on wood in southeastern blackwater streams (Benke et al. 1984; Smock et al. 1985) may result from high production of prey insects on wood in those streams (Benke et al. 1984). In Ozark streams the prey of odonates can be found in benthic and wood habitats in relatively similar densities, but in blackwater streams odonate nymphs evidently rely to a large extent on prey production from woody debris.

Overall differences in density from benthic and woody debris habitats between Ozark and southeastern blackwater streams indicate that megalopterans and odonates are confined to wood in blackwater streams because it is the only stable substrate. In Ozark streams, the benthic substrate is much larger-particled and more stable, promoting greater utilization of benthic habitats.

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TRACE METALS IN THE OYSTER,
CRASSOSTREA RHIZOPHORA, FROM THE
LAGUNA DE TERMINOS OF CAMPECHE, MEXICO

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Abstract.—Oysters (*Crassostrea rhizophora*) from the Laguna de Términos of Campeche, Mexico were analyzed for cadmium, copper, iron, manganese, lead and zinc. Dry weight concentrations of these metals ranged from 2.8 - 536 mg/kg with Zn > Fe > Cu > Mn > Pb > Cd. Results of this study are compared with concentrations of metals in the oyster *Crassostrea virginica* from other areas of Mexico as well as from the United States.

Resumen.—Las ostras (*Cassostrea rhizophora*) de la Laguna de Términos de Campeche, México fueron analizadas por cadmio, cobre, hierro, manganeso, plomo y cinc. Las concentraciones de estos metales oscilaban entre 2.8 y 536 mg/kg en peso seco con Zn > Fe > Cu > Mn > Pb > Cd. Estos resultados se comparan con los de las ostras (*Crassostrea virginica*) de otras partes de México y los Estados Unidos.

Mexico has an extension of about 12,555 km² of littoral lagoons. The pollution in these lagoons of the Gulf of Mexico is a primary result of man's activities such as food processing, petrochemical exploration, sugar refining, and agricultural and domestic wastewaters (Rosas et al. 1983). The Laguna de Términos represents an important ecosystem in the south of the Gulf of Mexico due to its valuable fish, oyster and wildlife resources (Yanez & Day 1988). The molluscs in the lagoon are abundant and species such as *Crassostrea virginica*, *Crassostrea rhizophora*, *Melongena melongena*, and *Pleuroloca gigantea* are commercially important.

Aquatic organisms can concentrate metals 10³ - 10⁶ times higher than the concentrations in the surrounding water (Phillips 1976). High level of metals are toxic and may interfere with the ecology of the aquatic environment (Bryan 1971). Trace metals concentrations in oysters have been extensively studied for this reason (Goldberg 1986; Presley et al. 1990; Vazquez et al. 1990; 1993a; 1993b; 1995). This study was undertaken to determine the concentration of trace metals (Cd, Cu, Fe, Mn, Pb, and Zn) in the oyster, *Crassostrea rhizophora*, collected from the Laguna de Términos of Campeche, Mexico, in order to establish the levels of metal pollution in Mexican oysters.

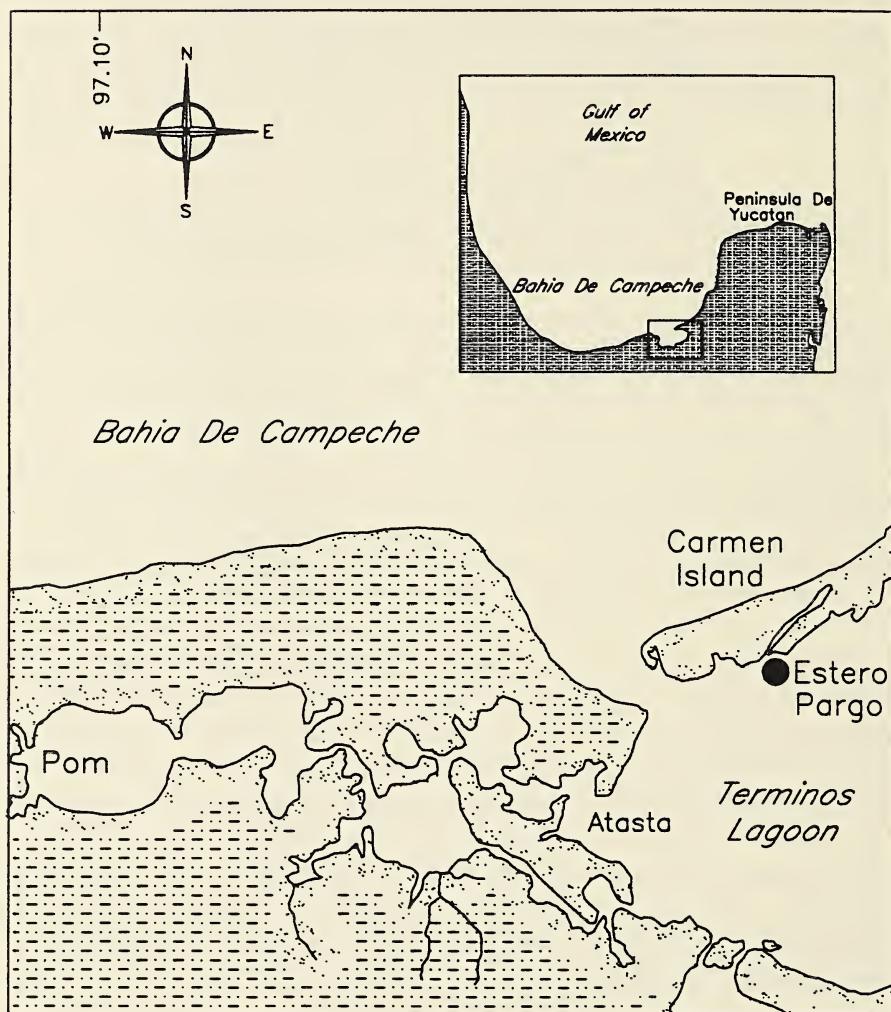


Figure 1. Study area in the Laguna de Términos and location of sampling site.

METHODS AND MATERIALS

Oyster specimens were hand-collected over seven months during the period of March to November, 1988 from the Estero Pargo station (Fig. 1). Specimens were stored in plastic bags and frozen at -20°C until

Table 1. Trace metals concentrations (mg/kg dry weight) in the oyster, *Crassostrea rhizophora* from Laguna Términos, Campeche, Mexico in 1988.

Month	Cd	Cu	Fe	Mn	Pb	Zn
March	3.4	72	350	14	15.0	315
April	3.1	71	302	14	10.0	306
May	3.0	78	295	14	1.0	400
June	3.0	120	460	16	12.0	415
August	3.1	88	470	16	13.0	446
September	1.2	125	661	15	5.0	721
November	2.8	175	704	19	7.8	1150
Mean	2.8	104	463	15	9.2	536
SD	0.7	38	165	2	4.9	304

required for analysis. The complete animals (without shell) were then freeze-dried, and subsamples of about 1g were homogenated with teflon pestles before conducting analysis.

The extraction of metals was performed by using acid digestion bombs (with a teflon cup) with concentrated nitric and hydrochloric acids (Presley et al. 1990). The glassware utilized was soaked in 1:3 nitric acid and hydrochloric acid, rinsed with Milli-Q water (doubly distilled water passed through Milli-Q Plus Water System, Millipore Corporation, Massachusetts) and maintained at 110°C prior to its use. The reagents utilized were of high purity and appropriate for trace metal analysis (Kremling 1983). The standards were made from commercially available stock solutions (Tritisol, Merck).

Metal concentrations were determined on a Perkin Elmer 2380 atomic absorption spectrophotometer equipped with a graphite furnace Model MGA-400. Standard solutions were prepared by dissolving metals in 1:1 nitric acid and hydrochloric acid. Three replicates were prepared and the precision of the trace metal analysis was estimated to be 10%.

RESULTS AND DISCUSSION

The concentrations of trace metals in *C. rhizophora* from the study site are presented in Table 1. In general, this study found relatively little variation in the concentrations of metals with season. Metal concentration ranges (mg/kg dry weight) included: Cd (1.2 - 3.4 mg/kg), Cu (71 - 175 mg/kg), Fe (295 - 704 mg/kg), Mn (14 - 19

Table 2. Comparison of mean trace metals concentrations (mg/kg/dry weight) in Gulf of Mexico oysters.

	Cd	Cu	Fe	Mn	Pb	Zn
<i>C. rhizophora</i> Laguna de Términos (this study)	2.8	104	463	15	9.2	536
<i>C. virginica</i> Laguna de Términos (Vasquez et al. 1993a)	4.1	326	949	38	8.8	628
<i>C. virginica</i> San Andres Lagoon (Vasquez et al. 1990)	2.5	48	64	27	5.8	3124
<i>C. virginica</i> United States (Presley et al. 1990)	3.8	123	252	12.5	0.45	1730

mg/kg), Pb (1.0 - 13 mg/kg), Zn (306 - 1150 mg/kg). Overall, mean metal concentrations ranged from 2.8 - 536 mg/kg dry weight and decreased in the order Zn > Fe > Cu > Mn > Pb > Cd (Table 2).

Comparison of these results with data for the oyster, *C. virginica* from this area is given in Table 2. Higher concentrations of trace metals, except Pb, were found in *C. virginica* than in *C. rhizophora*. This elevated concentration was probably related to habitat. *Crassostrea rhizophora* normally lives in high saline water whereas *C. virginica* lives in estuarine water with less salinity. There are several pathways in which organisms uptake metals and all, some, or none of the pathways are utilized depending on the habitat (Connell et al. 1991; Adriano 1992). Metal concentrations in oysters of San Andres Lagoon were lower, except for zinc, than in Laguna de Términos. The discharges of oil industries and of the Usumacinta/Grijalva River system (the largest in Mexico and second largest in the Gulf of Mexico) influence the coastal waters of the Laguna de Términos and may have been responsible for the higher accumulation of metals in the oysters.

Metals concentrations in general for *C. virginica* from the U. S. Gulf of Mexico were lower than that of Mexican oysters. Lead concentrations, however, in Mexican oysters were much higher than U. S. Gulf of Mexico oysters. Vasquez et al. (1993b) also found high concentrations of Pb in San Andres Lagoon waters. Higher concentrations of Pb

and other trace metals may be controlled by minimizing industrial effluents into the Mexican lagoons.

In summary, the Campeche Sound region of the Laguna de Términos is under development by the oil industry, therefore, there is clearly a case for the establishment of a long-term monitoring program to identify future changes in contamination levels. The present results are baselines.

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TRENDS IN WATER AND SEDIMENT QUALITY FOR THE HOUSTON SHIP CHANNEL

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Abstract.—Ambient monitoring data collected by the Texas Natural Resource Conservation Commission from 1971 through 1991 were assessed for five stations located on the Houston Ship Channel mainstem (Turning Basin, Greens Bayou, San Jacinto Monument, Channel Marker 120 and Morgans Point). Water quality was most impacted in the upper channel, especially at the Turning Basin, improving downstream of the San Jacinto River confluence. This is consistent with the more confined physical characteristics and the high degree of point and non-point source pollutant loading in the upper channel. Water quality has improved over the last couple of decades as demonstrated by declining trends for total organic carbon, total suspended solids, fecal coliforms, ammonia nitrogen, orthophosphate, total phosphate, total arsenic and total copper. Increases in nitrate nitrogen, over time were found at all sites. Declining trends for total cadmium, mercury, nickel and zinc were found for the upper (industrialized) portion of the channel only. Other findings for total metals indicated site-specific differences for silver, possible increasing trends for selenium and no trends for chromium. Increasing dissolved oxygen and decreasing biochemical oxygen demand and Kjeldahl nitrogen concentrations were evident at the upstream stations but, unexpectedly, trends reversed further downstream. Concentrations of heavy metals and PCBs in bottom sediment were greatest in the Turning Basin and dropped progressively downstream. Levels of arsenic, cadmium, lead and zinc in Turning Basin sediments decreased significantly over time. Improving water and sediment quality has enhanced utilization of the Ship Channel system by aquatic life.

The Houston Ship Channel (HSC) is located in Harris County within the San Jacinto River Basin on the southeast Texas coast. The inland portion of the HSC, comprised of state water quality segments 1005, 1006 and 1007 (TWC 1991), extends a distance of 25 miles between the mouth at Morgans Point to the Turning Basin (Fig. 1). Water quality in the HSC is influenced by a variety of point and nonpoint sources. The Port of Houston serves as the third leading shipping terminal in the U.S. Long-term impacts result from the nearly constant ship traffic as well as episodic discharges and spills. Periodic dredging is conducted to accommodate heavy ship and barge traffic. The HSC is heavily impacted by point sources from both municipal and industrial facilities. The HSC and its tributaries are the receiving waters for approximately 400 permitted industrial and municipal discharges (TDWR 1984). Oil, steel and petrochemical industries along the HSC make it one of the most highly industrialized waterbodies in the world. Fifty-five percent of the U.S. production of polypropylene and 34% of the polyethylene

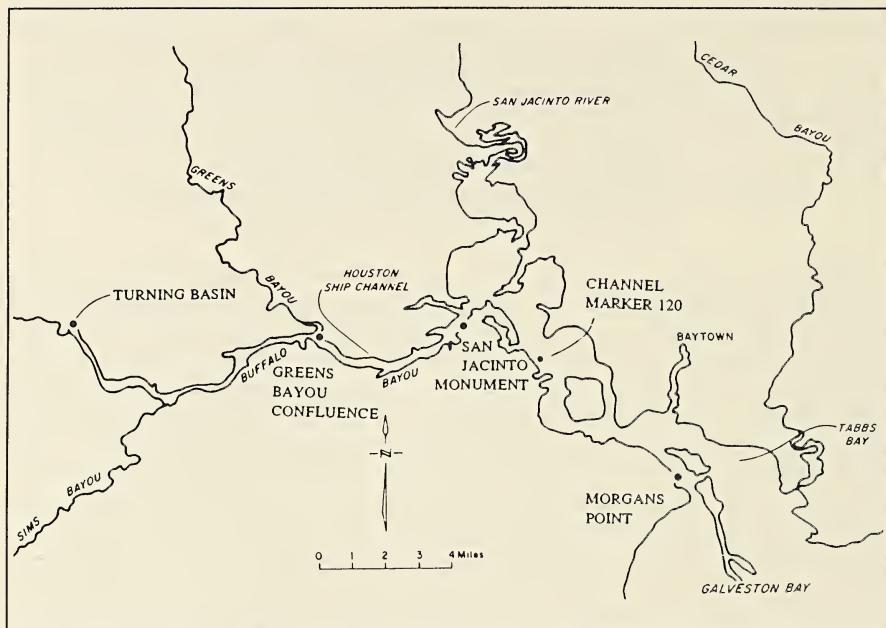


Figure 1. Map showing locations of monitoring stations. TWC (1991) delineates segments as follows: 1005 - San Jacinto R. to mouth; 1006 - Greens B. to San Jacinto R.; and 1007 - Turning Basin to Greens B.

originates from industries located on the HSC. The point source influence has resulted in an effluent dominated, tidally mediated flow regime.

The system is also impacted by urban runoff from the cities of Houston, Pasadena, Deer Park and others located on the HSC and its tributaries. Other potentially important nonpoint pollutant pathways include groundwater and atmospheric deposition. Numerous tidal bayous heavily influence water quality conditions in the HSC. In spite of the relatively high probability for water column impact recent investigations have revealed fewer than expected water quality criteria exceedances (Crocker et al. 1991). While it may be presumed that enhanced point source pollution controls are improving water quality, to date trends for chemical pollutants have not been adequately verified and documented.

The purpose of this report is to evaluate and document water quality trends for the HSC during the last 10 to 20 years (1970-1991). This evaluation does not serve to assess the abundance of data and information available, nor does it attempt to take into account every possible parameter and sampling location. Rather, it should be considered a preliminary evaluation in that only selected water and sediment quality

Table 1. State water quality monitoring program station locations.

Station Number	River Mile Upstream from Mouth	Location	Latitude	Longitude
1007.0800	24.8	HSC at Turning Basin	29° 45' 00"	95° 17' 20"
1006.0200	15.8	HSC at Greens Bayou	29° 44' 50"	95° 10' 04"
1006.0100	10.0	HSC at San Jacinto Monument	29° 45' 15"	95° 05' 30"
1005.0200	7.1	HSC at Channel Marker 120	29° 44' 30"	95° 03' 36"
1005.0100	0.4	HSC at Morgans Point	29° 40' 40"	94° 58' 45"

parameters were considered at five locations on the HSC. This article was adapted from a technical report prepared by the United States Environmental Protection Agency (Crocker et al. 1992).

METHODS AND MATERIALS

One of the most extensive databases available for assessing trends in the HSC is the Texas Natural Resource Conservation Commission's (TNRCC) State Water Quality Monitoring Program (SWQMP). These data were accessed through STORET, the U.S. EPA's national water quality database. The five stations included in this study are listed in Table 1. A map depicting station locations is presented in Figure 1. The water quality parameters evaluated include: (1) conventional parameters - dissolved oxygen (DO), total suspended solids (TSS), fecal coliforms, 5 day biochemical oxygen demand (BOD) and total organic carbon (TOC); (2) nutrients - ammonia ($\text{NH}_4\text{-N}$), nitrite ($\text{NO}_2\text{-N}$), nitrate ($\text{NO}_3\text{-N}$), total Kjeldahl nitrogen, orthophosphate (expressed as P by multiplying PO_4 by 0.333), and total phosphorus; and (3) heavy metals (total) - arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag) and zinc (Zn). Several heavy metals (As, Cd, Cu, Pb, Zn) and PCBs in bottom sediments were also evaluated. The period of record varied by parameter, with some nutrients and conventional parameters extending up to 20 years. With the exception of DO which was sampled at multiple depths, ambient water was sampled at the surface (approx. 1 ft depth).

Water quality data were retrieved from STORET using the PGM=RET program, and trends were assessed using the SAS "CORR" procedure (SAS 1990). This procedure allows one to correlate concentrations of given parameters with other parameters, or with time. Correlations between time and the concentration of parameters of interest served as the basis for making inferences regarding trends. Three separate statistical tests were performed to measure the association between time and parameter concentration: (1) Pearson Product Moment Correlation -

a parametric test assuming a normal distribution, considered to be the most powerful of the three procedures; (2) Spearman's Ranked Order Correlation - a nonparametric measure that is calculated as the correlation of the ranks of the variables; and (3) Kendall's tau-b - a nonparametric measure calculated from the number of concordant and discordant pairs of observations and uses a correlation for tied pairs (i.e., pairs of observations that have equal values of x or equal values of y). All data, including remarked data (e.g., designated as "less than") were included in the analysis. The remarked data were set at the remarked value, which was generally the detection limit. The null hypothesis was that there was no significant correlation between time and parameter concentration (i.e., $H_0: \text{Rho}=0$).

Use of multiple statistical analyses was considered advantageous to improve certainty and representativeness of the trends results. For example, the assumption of normality may not hold, thus compromising the representativeness of the Pearson Correlation. Agreement by all three tests would indicate a high degree of confidence in the interpretation of trends. Pearson, Spearman and Kendall statistics are summarized in a tabular format. Trends for each specific statistical test were considered to be significantly increasing or declining at a probability level greater than or equal to 95% (i.e., $P \geq 0.95$). Trends over time were considered possibly significant if the probability was greater than or equal to 90% but less than 95% (i.e., $0.90 \leq P < 0.95$). The authors believe the Spearman and Kendall tau-b statistic are most defensible as most water quality parameters are unlikely to be normally distributed.

The SAS CORR program calculated average concentrations for the various parameters over the period of record. The STORET PGM=Plot program furnished the slope of the least squares regression line. Average concentrations, standard deviation, and slopes are included in the parameter by parameter tabulation of results. Statistical data summaries are contained Crocker et al. (1992: Appendices).

Lastly, graphs of cumulative point source discharge flow and loading of BOD and NH₄-N were prepared using data (1984-91) submitted periodically by the TNRCC to the U.S. EPA.

RESULTS

Results on temporal trends are presented in Tables 2, 3, 4 and 5. Data on discharge flow, and point source loadings for NH₄-N and BOD are presented in Figure 2. The data are discussed by parameter groupings below.

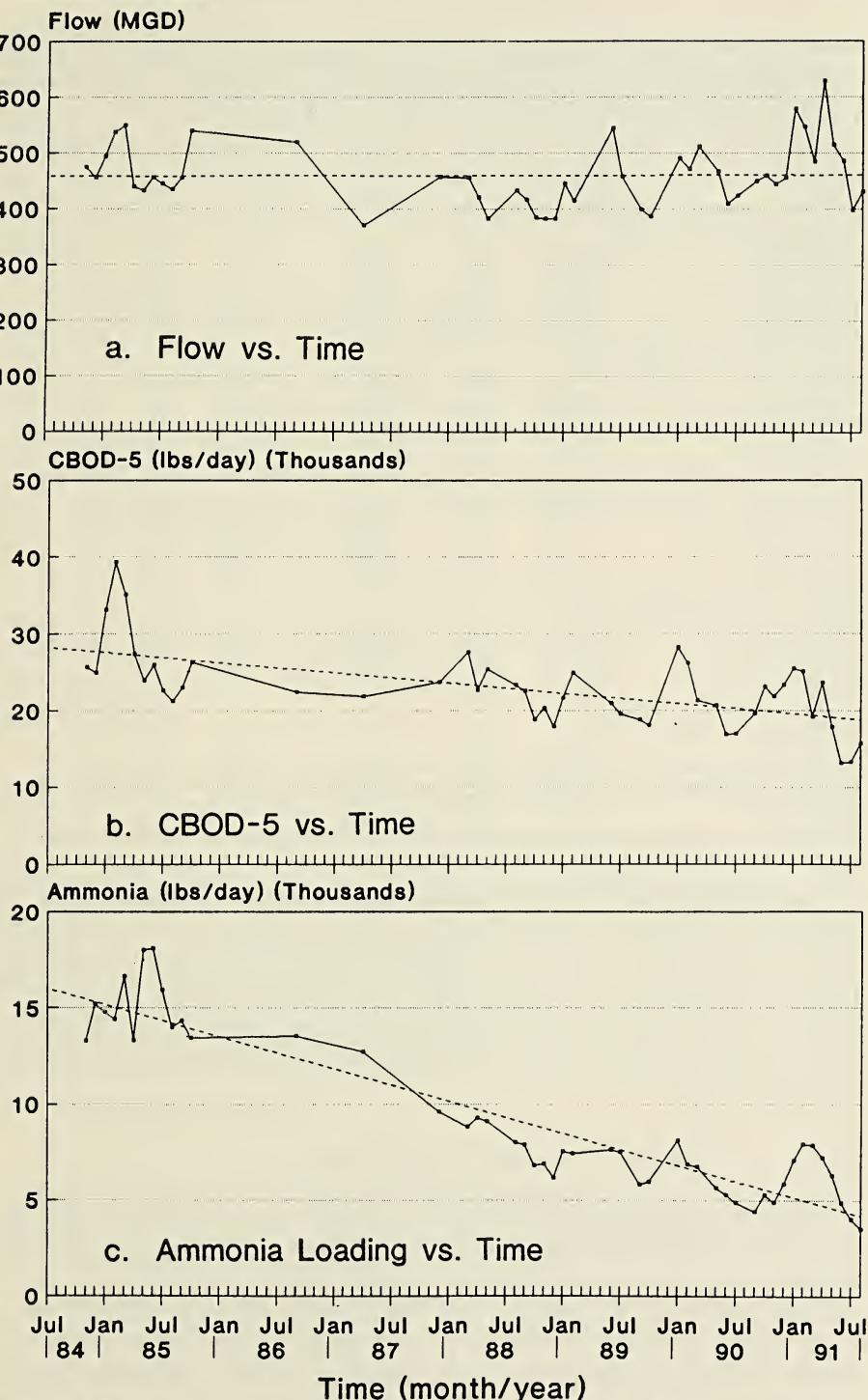


Figure 2. Temporal changes in point source (a) discharge flows, (b) BOD loading and (c) $\text{NH}_4\text{-N}$ loading.

Table 2. Field and conventional parameters. Long-term mean, standard deviation and relationship with time. Statistical trend depicted as follows: ↑=apparent increasing trend; ↓=apparent decreasing trend; ~↑/↓ possible increasing/decreasing trend; and —= no apparent trend. Pearson, Spearman and Kendall-tau trends are abbreviated as P,S and K.

Parameter (Stonet Code)	Slope (Units/Year)	N	Period of Record	Trend				
				Mean	SD	P	S	K
<u>Dissolved Oxygen (00300), mg/L</u>								
Turning Basin	+0.103	1081	1970-91	1.57	2.08	↑	↑	↑
Greens Bayou	+0.392	531	1982-91	3.25	2.22	↑	↑	↑
San Jacinto Monument	+0.321	462	1971-91	4.51	2.29	↑	↑	↑
Ch. Marker 120	-0.093	391	1983-91	6.38	1.87	↓	—	—
Morgans Point	-0.149	420	1982-91	7.09	1.78	↓	↓	↓
<u>Total Suspended Solids (00530), mg/L</u>								
Turning Basin	-4.117	330	1970-91	41.64	58.42	↓	↓	↓
Greens Bayou	-1.924	222	1976-91	24.99	32.01	↓	↓	↓
San Jacinto Monument	-0.892	213	1976-91	29.88	27.74	↓	↓	↓
Ch. Marker 120	-1.637	206	1976-91	37.49	48.36	↓	↓	↓
Morgans Point	+0.127	233	1976-91	40.01	38.85	—	—	—
<u>Fecal Coliforms (31616), Colonies/100 mL</u>								
Turning Basin	-3,852	179	1973-91	27,116	65,299	↓	↓	↓
Greens Bayou	-973	144	1976-91	7,723	20,112	↓	↓	↓
San Jacinto Monument	-134	124	1976-91	2,255	5,843	—	↓	↓
Ch. Marker 120	-63	129	1976-91	558	1,137	↓	~↓	~↓
Morgans Point	-19	142	1976-91	229	698	—	—	—
<u>BOD - 5 Day (00310), mg/L</u>								
Turning Basin	-0.220	315	1970-89	6.59	8.48	↓	↓	↓
Greens Bayou	-0.039	191	1976-89	2.85	1.53	—	—	—
San Jacinto Monument	+0.014	179	1970-89	2.89	1.20	—	—	—
Ch. Marker 120	+0.056	174	1976-89	3.29	2.26	—	↑	↑
Morgans Point	+0.227	202	1976-89	3.47	2.77	↑	↑	↑
<u>Total Organic Carbon (00680), mg/L</u>								
Turning Basin	-0.331	293	1973-91	14.43	14.23	↓	↓	↓
Greens Bayou	-0.392	195	1976-91	12.39	5.54	↓	↓	↓
San Jacinto Monument	-0.383	183	1974-91	11.65	5.87	↓	↓	↓
Ch. Marker 120	-0.319	175	1976-91	11.30	6.54	↓	↓	↓
Morgans Point	-0.390	207	1976-91	9.43	6.01	↓	↓	↓

In considering these data it should be recognized that trends are not necessarily absolute. The validity of trends hinges on the amount of data and the assumption that statistical tests are adequate to demonstrate patterns in the data. It is important to realize that detection levels for most of the parameters assessed have declined during the last 10-20 years. It is possible that trends may be influenced by lowering of detection levels.

ANALYSIS OF TRENDS

Field and conventional parameters (Table 2).—The trends analysis took into account DO data collected at surface, bottom as well as other depths. As would be expected, long-term mean concentrations were lowest at the Turning Basin (1.57 mg/L) and increased progressively downstream to Morgans Point (7.09 mg/L). Significant increasing trends in DO concentrations were apparent at the Turning Basin, Greens Bayou and San Jacinto Monument. Unexpectedly, the trend for DO

further downstream at Channel Marker 120 and Morgans Point was decreasing. Low DO in the Turning Basin corresponded with high BOD. Temporal reductions in BOD suggest improved control of BOD by upstream municipal dischargers. Point source BOD loading to the HSC during 1984-91 decreased steadily while discharge flow remained constant (Fig. 2 A & B). Loading of BOD was greatest during winter months.

Concentrations of TSS were highest at the Turning Basin and Morgans Point, but site specific differences were slight. Downward trends were evident at all stations except for Morgans Point. The strongest trend was at the Turning Basin where TSS was decreasing approximately 4 mg/L/yr. A large amount of TOC data were available for all stations. Compared with other sites, TOC was slightly higher at the Turning Basin, with strong, uniform decreasing trends (-0.3 to -0.4 mg/L/yr) throughout the system.

The fecal coliform data displayed a dominant spacial trend; high upstream, much lower downstream. The Morgans Point average approached the state water quality standard of 200 colonies/100 mL. Decreasing trends were proportional to the long-term mean concentrations.

Nitrogen and phosphorus (Table 3).—With the exception of NO₂-N, concentrations of nitrogen compounds (NH₄-N, NO₃-N, TKN) were highest at the Turning Basin and decreased progressively to Morgans Point. Significant declines in NH₄-N and increases in NO₃-N were observed for each station. These findings appear to reflect the dramatic reductions in loading resulting from increased sewage treatment efficiency demonstrated during 1984-91 (Fig. 2C). Levels of NO₂-N were relatively low overall, and were lowest at the Turning Basin and Morgans Point. The more subtle increases observed for NO₂-N may be due to effective oxidation of NH₄-N to nitrate in treatment plants or *in situ* within the waterbody.

Data on PO₄ were not available after 1985. For both PO₄ and total P, mean values were highest at the Turning Basin and Greens Bayou and decreased at downstream stations. Downward trends were apparent at all stations, although were least extreme at Morgans Point.

Total heavy metals (Table 4).—Little spacial disparity for total concentrations of As, Cd, Pb, Cr and Ag was observed. Decreasing trends were evident for As, Cd and to some degree Pb. Increasing

Table 3. Nitrogen and phosphorus. Long-term mean, standard deviation and relationship with time. Statistical trend depicted as follows: \uparrow = apparent increasing trend; \downarrow = apparent decreasing trend; $\sim \uparrow / \sim \downarrow$ possible increasing/decreasing trend; and $=$ no apparent trend. Pearson, Spearman and Kendall-tau trends are abbreviated as P, S and K.

Parameter (Storet Code)	Slope (Units/Year)	Period of Record			Trend		
		Station	N	Mean	SD	P	S
<u>Ammonia-Nitrogen (00610), mg/L</u>							
Turning Basin	- 0.311	324	1970-91	2.91	3.24	\downarrow	\downarrow
Greens Bayou	- 0.156	218	1976-91	1.72	1.41	\downarrow	\downarrow
San Jacinto Monument	- 0.084	203	1976-91	0.95	0.77	\downarrow	\downarrow
Ch. Marker 120	- 0.042	198	1976-91	0.56	0.50	\downarrow	\downarrow
Morgans Point	- 0.011	227	1976-91	0.23	0.24	\downarrow	\downarrow
<u>Nitrate (00620), mg/L</u>							
Turning Basin	+ 0.148	323	1972-91	0.65	1.11	\uparrow	\uparrow
Greens Bayou	+ 0.108	219	1976-91	0.63	0.75	\uparrow	\uparrow
San Jacinto Monument	+ 0.063	204	1976-91	0.53	0.55	\uparrow	\uparrow
Ch. Marker 120	+ 0.044	198	1976-91	0.42	0.42	\uparrow	\uparrow
Morgans Point	+ 0.029	226	1976-91	0.29	0.68	\uparrow	\uparrow
<u>Nitrite (00615), mg/L</u>							
Turning Basin	+ 0.007	144	1976-91	0.12	0.21	$\sim \uparrow$	$\sim \uparrow$
Greens Bayou	+ 0.015	188	1977-91	0.25	0.29	\uparrow	\uparrow
San Jacinto Monument	+ 0.004	172	1977-91	0.27	0.28	\uparrow	\uparrow
Ch. Marker 120	+ 0.003	163	1977-91	0.23	0.24	\sim	\uparrow
Morgans Point	- 0.001	130	1977-91	0.10	0.11	\sim	\sim
<u>Total Kjeldahl Nitrogen (00625), mg/L</u>							
Turning Basin	- 0.236	198	1976-91	3.93	3.87	\downarrow	\downarrow
Greens Bayou	- 0.104	148	1977-89	3.09	1.14	\downarrow	\downarrow
San Jacinto Monument	- 0.053	133	1977-91	2.31	0.94	\downarrow	\downarrow
Ch. Marker 120	+ 0.008	131	1977-89	1.87	0.80	\sim	\sim
Morgans Point	+ 0.055	171	1977-91	1.52	0.75	\uparrow	\uparrow
<u>Orthophosphate (00660), mg/L</u>							
Turning Basin	- 0.046	254	1973-85	1.57	0.70	\downarrow	\downarrow
Greens Bayou	- 0.123	158	1976-85	1.68	1.07	\downarrow	\downarrow
San Jacinto Monument	- 0.045	141	1976-85	1.10	0.50	\downarrow	\downarrow
Ch. Marker 120	- 0.029	143	1976-85	0.79	0.36	\downarrow	\downarrow
Morgans Point	- 0.012	159	1976-85	0.49	0.21	$\sim \downarrow$	$\sim \downarrow$
<u>Total Phosphorus (00665), mg/L</u>							
Turning Basin	- 0.039	323	1972-91	1.88	1.02	\downarrow	\downarrow
Greens Bayou	- 0.070	217	1976-91	1.71	0.93	\downarrow	\downarrow
San Jacinto Monument	- 0.039	202	1976-91	1.14	0.51	\downarrow	\downarrow
Ch. Marker 120	- 0.028	195	1976-91	0.88	0.40	\downarrow	\downarrow
Morgans Point	- 0.013	225	1976-91	0.54	0.22	\downarrow	\downarrow

trends for Pb were found at San Jacinto Monument. Temporal trends in Ag differed from site to site, with the most pronounced increase also being at San Jacinto Monument. No trends were found for Cr. Levels of Cu, Ni and Zn were most elevated at the Turning Basin, decreased downstream in segment 1006, and increased slightly in segment 1005, perhaps due to point source inputs. Significant declining trends were found for Cu at each station, and at the upper station(s) for Ni and Zn. Data were limited for Se but this parameter was interesting in that the spacial pattern differed from most other parameters: concentrations increased from upstream to downstream. Also surprising were the positive slopes at all stations, with significant increasing trends at San Jacinto Monument and Channel Marker 120.

Table 4. Total heavy metals. Long-term mean, standard deviation and relationship with time. Statistical trend depicted as follows: ↑ = apparent increasing trend; ↓ = apparent decreasing trend; ~↑/~↓ possible increasing/decreasing trend; and — = no apparent trend. Pearson, Spearman and Kendall-tau trends are abbreviated as P,S and K.

Parameter (Storet Code)	Slope (Units/Year)	N	Period of Record	Trend			
				Mean	SD	P	S
<u>Total Arsenic (01002), ug/L</u>							
Turning Basin	- 3.192	67	1973-90	22.08	34.87	↓	↓
Greens Bayou	- 2.293	46	1976-90	22.56	18.89	↓	↓
San Jacinto Monument	- 1.251	48	1976-88	20.03	17.99	~↓	↓
Ch. Marker 120	- 1.837	45	1973-88	20.49	22.32	↓	↓
Morgans Point	- 0.348	46	1976-89	18.13	13.24	—	~↓
<u>Total Cadmium (01027), ug/L</u>							
Turning Basin	- 0.342	91	1973-90	10.45	5.33	↓	~↓
Greens Bayou	- 0.388	46	1976-90	11.39	7.04	—	↓
San Jacinto Monument	- 0.451	48	1976-88	11.29	4.99	↓	↓
Ch. Marker 120	- 0.248	45	1974-88	12.69	7.92	—	—
Morgans Point	- 0.500	46	1976-89	14.63	9.47	—	—
<u>Total Chromium (01034), ug/L</u>							
Turning Basin	- 0.437	85	1973-90	23.99	20.85	—	—
Greens Bayou	- 4.410	39	1976-90	39.87	94.63	—	—
San Jacinto Monument	+0.157	41	1976-88	24.63	15.17	—	—
Ch. Marker 120	+0.424	38	1973-88	24.89	12.44	—	—
Morgans Point	+0.239	40	1976-89	26.98	12.86	—	—
<u>Total Copper (01042), ug/L</u>							
Turning Basin	- 15.423	91	1973-90	176.07	173.25	↓	↓
Greens Bayou	- 11.192	46	1976-90	82.28	115.18	↓	↓
San Jacinto Monument	- 10.105	48	1976-88	82.80	114.73	↓	↓
Ch. Marker 120	- 11.613	45	1973-88	79.76	102.87	↓	↓
Morgans Point	- 13.500	46	1976-88	91.74	149.20	↓	↓
<u>Total Lead (01051), ug/L</u>							
Turning Basin	- 3.299	90	1973-90	55.92	46.31	↓	↓
Greens Bayou	- 0.010	45	1976-90	39.29	29.00	—	—
San Jacinto Monument	+1.764	47	1976-88	46.51	33.44	—	↑
Ch. Marker 120	- 0.309	44	1973-88	45.95	40.76	—	—
Morgans Point	- 0.190	45	1976-89	57.99	45.35	—	—
<u>Total Mercury (71900), ug/L</u>							
Turning Basin	- 0.042	91	1973-90	0.46	0.52	↓	↓
Greens Bayou	- 0.020	46	1977-90	0.42	0.81	—	—
San Jacinto Monument	- 0.005	48	1976-88	0.32	0.27	—	—
Ch. Marker 120	- 0.083	45	1973-88	0.63	1.80	—	—
Morgans Point	+0.011	45	1976-89	0.35	0.50	—	—
<u>Total Nickel (01067), ug/L</u>							
Turning Basin	- 10.232	49	1973-90	118.90	90.57	↓	↓
Greens Bayou	+2.025	11	1983-90	17.55	16.46	—	—
San Jacinto Monument	- 0.025	11	1983-88	14.18	5.55	—	—
Ch. Marker 120	- 7.192	9	1973-88	21.56	33.72	↓	—
Morgans Point	+0.975	10	1983-89	21.70	13.42	—	—
<u>Total Selenium (01147), ug/L</u>							
Turning Basin	+0.312	14	1973-90	6.21	6.29	—	—
Greens Bayou	+2.777	11	1983-90	17.07	21.38	—	—
San Jacinto Monument	+7.609	11	1983-88	19.71	20.07	~↑	↑
Ch. Marker 120	+13.620	8	1983-88	24.11	28.32	~↑	↑
Morgans Point	+6.567	10	1983-89	30.95	34.41	—	—
<u>Total Silver (01077), ug/L</u>							
Turning Basin	- 0.448	68	1973-90	11.04	8.67	↓	~↓
Greens Bayou	+2.872	11	1983-90	13.09	10.60	—	—
San Jacinto Monument	+3.638	11	1983-88	12.45	10.29	—	↑
Ch. Marker 120	- 0.134	9	1973-88	13.22	12.16	—	—
Morgans Point	+1.110	23	1980-89	12.39	7.49	↑	↑
<u>Total Zinc (01092), ug/L</u>							
Turning Basin	- 16.002	72	1973-90	236.46	275.60	↓	↓
Greens Bayou	- 6.416	14	1976-90	79.29	61.03	~↓	↓
San Jacinto Monument	- 1.928	14	1976-88	96.50	63.89	—	—
Ch. Marker 120	- 1.250	12	1974-88	107.25	79.11	—	—
Morgans Point	- 1.507	27	1976-89	86.67	80.72	—	—

Table 5. Heavy metals and PCB's in bottom sediment. Long-term mean, standard deviation and relationship with time. Statistical trend depicted as follows: ↑=apparent increasing trend; ↓=apparent decreasing trend; ~↑/~↓ possible increasing/decreasing trend; and —=no apparent trend. Pearson, Spearman and Kendall-tau trends are abbreviated as P,S and K.

Parameter (Storet Code)	Slope (Units/Year)	N	Period of Record	Mean	SD	Trend		
						P	S	K
<u>Arsenic in Bottom Sediment (01003), mg/kg</u>								
Turning Basin	- 0.717	13	1977-90	6.96	4.50	↓	↓	↓
Greens Bayou	- 0.382	8	1977-87	6.91	2.79	—	—	—
San Jacinto Monument	- 0.428	8	1977-90	6.54	5.09	—	↓	~↓
Morgans Point	- 0.502	10	1977-90	5.21	2.81	↓	↓	↓
<u>Cadmium in Bottom Sediment (01028), mg/kg</u>								
Turning Basin	- 0.354	18	1974-90	5.23	2.88	↓	↓	↓
Greens Bayou	- 0.014	8	1977-87	1.93	1.22	—	—	—
San Jacinto Monument	- 0.065	8	1977-90	2.43	2.16	—	—	—
Morgans Point	- 0.117	10	1977-90	1.59	1.36	—	—	—
<u>Copper in Bottom Sediment (01043), mg/kg</u>								
Turning Basin	- 2.642	18	1974-90	54.29	36.55	—	—	~↓
Greens Bayou	+1.934	8	1977-87	34.39	12.47	—	—	~↑
San Jacinto Monument	+0.943	8	1977-90	17.40	8.98	—	—	—
Morgans Point	- 0.028	10	1977-90	11.92	4.29	—	—	—
<u>Lead in Bottom Sediment (01052), mg/kg</u>								
Turning Basin	- 10.518	18	1974-90	177.76	86.98	↓	↓	↓
Greens Bayou	- 4.454	8	1977-87	57.01	39.90	—	—	—
San Jacinto Monument	+5.928	8	1977-90	56.76	35.21	↑	—	—
Morgans Point	+2.232	10	1977-90	28.75	15.55	↑	—	—
<u>Zinc in Bottom Sediment (01093), mg/kg</u>								
Turning Basin	- 41.448	18	1974-90	540.92	336.97	↓	↓	↓
Greens Bayou	+8.415	8	1977-87	182.88	52.91	—	↑	↑
San Jacinto Monument	+0.414	8	1977-90	89.19	58.83	—	—	—
Morgans Point	+0.988	10	1977-90	63.89	25.44	—	—	—
<u>PCBs in Bottom Sediment (39519), ug/kg</u>								
Turning Basin	- 70.810	11	1974-90	1039.51	2079.43	—	—	—
Greens Bayou	+31.940	5	1978-87	413.24	428.72	—	—	—
San Jacinto Monument	- 6.301	13	1978-90	90.79	163.76	—	—	—
Morgans Point	- 0.894	8	1978-90	16.11	7.21	—	—	—

Heavy metals and PCBs in bottom sediment (Table 5).—Monitoring of heavy metals in bottom sediments has been relatively limited, therefore the data are probably insufficient to develop definitive conclusions concerning trends. Long et al. (1995) present chemical specific Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values indicative of threshold and probable toxic effects to benthic organisms, respectively. Long-term averages exceeded ER-Ms for Zn and PCBs at the Turning Basin and Greens Bayou. ER-Ls were exceeded for Cu at these same stations, PCBs at San Jacinto Monument, and Pb at the Turning Basin, Greens Bayou and San Jacinto Monument. Note however that averages using recent data for most or all of these parameters would tend to be lower than the long-term averages presented in Table 5. For the four stations with data, concentrations fell into the following pattern: Zn > Pb > Cu > As > Cd. In all cases average concentrations for metals were highest at the Turning Basin and decreased progressively downstream. As was decreasing at the Turning

Basin and Morgans Point, and possibly at San Jacinto Monument. Cd, Pb and Zn were significantly decreasing at the Turning Basin. PCBs in bottom sediments were also highest (1040 ug/kg) at the Turning Basin, with a notable decreasing pattern downstream. There were insufficient data to conclusively establish trends for PCBs.

DISCUSSION

As a whole the three statistical approaches used to evaluate temporal trends were very comparable. There was close agreement for virtually all parameters; this tends to solidify our conclusions. However, for most screening type assessments one or possibly two statistical analyses (e.g., Kendall tau-b or Spearman) should be adequate. Trends studies such as this are useful for determining the need for water quality management relative to point or non-point discharges. It is particularly relevant to periodically review fixed station ambient monitoring data for urban watersheds and around heavy concentrations of industrial or municipal discharges. Such assessments often lead to more detailed evaluations of specific water quality parameters or waterbodies of concern.

Dissolved oxygen.—In spite of improvements in wastewater treatment DO continues to be a long-term issue primarily in the upper portion of the HSC, especially the Turning Basin. Previous studies (Crocker et al. 1991; Guillen 1993) have demonstrated a pronounced depletion of DO with depth in the Turning Basin, and to a lesser extent downstream where there are fewer pollutant sources and tidal mixing is improved. Hypoxic/anoxic conditions are most extreme during hot, dry, calm, cloudy weather conditions. Ward & Armstrong (1992) documented DO stratification in the HSC to be on the order of 0.2 mg/m. They reported that the HSC had the lowest mean DOs in the Galveston Bay system. Their trends analysis agreed with this study in that they found gradually improving trends with a negative deficit of 0.1 mg/L/yr.

Existing water quality standards (WQS) are low, 1.0 mg/L and 2.0 mg/L for segments 1007 and 1006, respectively. While these standards would be expected to hamper improvement, it is encouraging to observe an increasing DO trend in the upper HSC. Contrary to the upper HSC, negative slopes were found for DO at Morgans Point. The reason for this is unknown, although it is possible that point source BOD loading in segment 1005 may also be increasing (0.227 mg/L/yr). Another possible reason is that there may be a decrease in phytoplankton blooms which influence surface DOs, often causing supersaturation.

Guillen (1993), who evaluated data from 1969-1990, found increasing trends in DO, with the rate of increase most extreme in Buffalo Bayou and the Turning Basin. Contrary to the slight decreasing trend found at Morgans Point in the present study, Guillen (1993) did not find a significant ($P=0.95$) trend in DO for this station. Surface and bottom DO trends for Morgans Point were 0.03 mg/L/yr and 0.01 mg/L/yr , respectively, as compared to -0.15 mg/L/yr in the present study. This disparity may be explained by: (1) the slightly different period of record for the monitoring data; (2) DO data for all depths were combined in the present study (possibly causing a false trend), while Guillen (1993) treated the two datasets separately; and/or (3) differences in the computer analysis (e.g., Guillen seasonally adjusted the data, which was not conducted in the present study).

Nitrogen species.—Of interest was the finding of significant increasing trends at every station with the rate of increase proportional to the average concentrations (i.e., highest at Turning Basin, lowest at Morgans Point). The results suggest that municipal treatment plants are increasing efficiency with regard to discharges of $\text{NH}_4\text{-N}$, and the form of nitrogen is shifting to the more oxidized form, $\text{NO}_3\text{-N}$. An exhaustive correlation between different water quality parameters was not conducted. However, the statistical analysis included correlations between water quality parameters. $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were found to be inversely correlated at all five stations. The primary purpose of nitrification in sewage treatment is to reduce oxygen demand by converting ammonia to nitrate prior to discharge. The conversion of ammonia to nitrate has an important secondary benefit, by reducing the risk of ammonia toxicity to aquatic life. However, because phytoplankton can shift from $\text{NH}_4\text{-N}$ to other nitrogen sources, nitrification requirements do little or nothing to control nutrient enrichment effects.

Dissolved heavy metals.—Historical (1988-91) data collected by the TNRCC and EPA for all five stations indicated that Cu, Pb, Hg and Ni exceeded either the aquatic life or human health WQS in 17%, 10%, 30% and 31% of the samples, respectively. The state has not yet adopted human health WQS for As. When compared to the EPA criterion, 24% of the samples had concentrations higher than the criterion (Crocker et al. 1992).

The TNRCC is in the process of developing total maximum daily loads (TMDLs) for these metals which are designed to ensure attainment of water quality standards. Controversy has arisen regarding the validity of historical heavy metals monitoring data on a national basis due to the

high potential for contamination both during field collection and laboratory analysis. Heavy metal WQS are expressed as the dissolved fraction (except for the Hg human health WQS). Accordingly the TNRCC has expended considerable effort to incorporate "clean" techniques and lower detection levels to better assess WQS compliance. While the dissolved metals data evaluated here pre-dates the implementation of improved clean techniques, we have no compelling reasons from a quality assurance standpoint to discard the data.

It should be noted that recent data (ENSR 1995) using clean procedures indicated very low surface water concentrations of dissolved metals, although at a low percentage of sites (mainly tidal bayous) heavy metals (Cu, Hg) WQS exceedances were observed. The reason(s) for the differences between earlier and recent concentrations may relate to field/lab techniques, or they may be due to regulatory controls and/or voluntary reductions in point source discharges, atmospheric releases, and/or nonpoint sources. The factors responsible for the differences will more than likely remain a matter of conjecture.

Other environmental indicators.—While the emphasis of the present study was to assess chemical parameters, other biological indicators such as ambient water toxicity and the fish community are important in gauging water quality changes. Ambient water toxicity testing serves to estimate the cumulative toxicological effect of all pollutants present in the water column. Historical data for ambient toxicity are limited. Crocker et al. (1991) collected data for ambient toxicity for 12 stations in the HSC system. While the results were somewhat encouraging in that toxicity was less prevalent than expected, significant toxicity was found in the upper, industrialized portions of the HSC, and Greens and Sims Bayous. A subsequent study (ENSR 1995) found only a small proportion of sites tested had significant ambient toxicity, including Patricks, Brays and Vince Bayous, and the Turning Basin, although sediment toxicity was rather widespread.

Seiler et al. (1991) documented improvement and diversification of the fish community in segments 1006 and 1007 during 1988-89 compared to the mid-1970s. A total of 76 taxa were collected for segment 1006, and 59 for 1007, with 84 species collected overall. The upper HSC was used extensively as habitat for juvenile fishes and maintained invertebrates. Segment 1006 maintained a fairly diverse fish community throughout the year and even during periods of low DO, and segment 1007 sustained a viable shoreline assemblage of organisms.

The relatively low incidence of ambient toxicity (in the mainstem HSC) and the diverse fish community seem to parallel the overall improvements in chemical water quality parameters found in this study. Water quality is likely to continue to improve, although some "leveling off" of trends is expected based on technological constraints for point sources. Also due to the physical modifications and its predominant industrial water supply and navigation uses, the HSC will never achieve its former natural state. Future environmental monitoring and management will likely gradually expand to address bottom sediment quality and bioaccumulative pollutants. Due to the lack of fixed station monitoring, water and sediment quality trends for the tidal bayous are more problematic. While it is certain improvements have been realized, water and sediment quality in these tidal bayous are still a concern.

CONCLUSIONS

Statistical correlation (Pearson, Spearman and Kendall tau-b) was utilized to assess temporal trends for 21 water quality and six sediment quality parameters for five ambient stations on the HSC. Data for these TNRCC fixed stations was accessed using STORET. The available data indicated that overall water quality over the last couple of decades has improved markedly. Most encouraging were the apparent declining trends at all or the majority of stations for TOC, TSS, fecal coliforms, ammonia, orthophosphate, total phosphate, total arsenic and total copper. Declining trends for total Cd, Hg, Ni and Zn concentrations were found for upstream stations only, where concentrations were highest. Other findings for total metals included possible increasing trends for Se, site specific variability for Ag, and no apparent trends for Cr.

Increasing DO and decreasing BOD and Kjeldahl nitrogen were evident at the upstream stations (e.g., Turning Basin) but, unexpectedly, trends reversed further downstream (Morgans Point). A spacial pattern was demonstrated with these parameters, with DO increases and pollutant reductions over time most extreme at upstream stations. Increasing trends were found for nitrate and nitrite. Nitrate was inversely correlated with ammonia concentration, suggesting temporal improvements in municipal wastewater treatment.

Recent studies showing low incidence of ambient toxicity, and a fairly diverse aquatic community also indicate water quality improvement. The somewhat limited data for bottom sediments indicate no trends for PCBs and decreasing trends for As, Cd, Pb and Zn at the Turning Basin.

An evaluation of dissolved metals data for the HSC Channel during 1988-91 pointed to several of the metals as being a potential concern with regard to protection of aquatic life or human health: As, Cu, Pb, Hg and Ni. More recent data, however, indicate lower concentrations, which may be due to improved sampling and analysis techniques and/or pollutant reductions by dischargers.

Trend analyses were considered useful for assessing water quality monitoring data to aid in identifying segments and pollutants of concern, and to determine the effectiveness of pollution control efforts.

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URANIUM MINERALIZATION IN THE GOLIAD FORMATION OF THE KINGSVILLE DOME *IN SITU* LEACH URANIUM MINE IN KLEBERG COUNTY, TEXAS

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Abstract.—Most of the bedload fluvial sandstones of the Miocene Goliad Formation in the subsurface of the Kingsville Dome uranium mine area are litharenites and are host to uranium minerals in "roll-front" uranium deposits. The uranium roll-fronts occur in fluvial channel-fill deposits and the ore bodies formed when uranium-enriched groundwater invaded a zone that had been reduced by methane and hydrogen sulfide gases. These gases most likely migrated upwards through faults from deeper hydrocarbon reservoirs. The uranium ore occurs as uraninite and amorphous uranium in detrital iron-titanium oxide minerals which were subsequently replaced by marcasite, pyrite and titanomagnetite in the sand-size volcanic fragments, in diagenetic montmorillonite clay, and on the surfaces of thin authigenic Ca-montmorillonite clay coats surrounding quartz sand grains.

The Miocene Goliad Formation is the youngest geologic unit mined for uranium in the South Texas Uranium District. The Goliad Formation crops out at the surface approximately 96 km (60 mi) inland from the Gulf of Mexico. The area discussed in this paper includes a uranium-enriched portion of the Goliad Formation which occurs at the subsurface located in the southern portion of the Texas Coastal Plain, only 50 km (30 mi) west of the Gulf of Mexico. The Kingsville Dome uranium mining operations (Figure 1) are in Kleberg County approximately 13 km (8 mi) southeast of Kingsville and 6.5 km (4 mi) east of Ricardo, immediately south of Farm Rd 1118. The ore body occurs at depths of approximately 170 m (559 ft) and is located on the south flank of the Kingsville Dome, a deep non-pierceement diapir in the subsurface. Structures within the dome include down-to-the-coast faults in lower Frio sediments, northeast trending faults that form a graben complex (Sams 1970; W. Nollkamper, pers. comm.) in post-Frio sediments, and the northwest trending Santa Gertrudis fault. At the Kingsville Dome, the fault systems in the deeper hydrocarbon-bearing strata in conjunction with upward migration of methane gas along fault zones are responsible for contributing to the development of this uranium deposit (R. Clement, pers. comm.) because the gases migrating upward through the faults caused localized precipitation of uranium in the Goliad Formation.

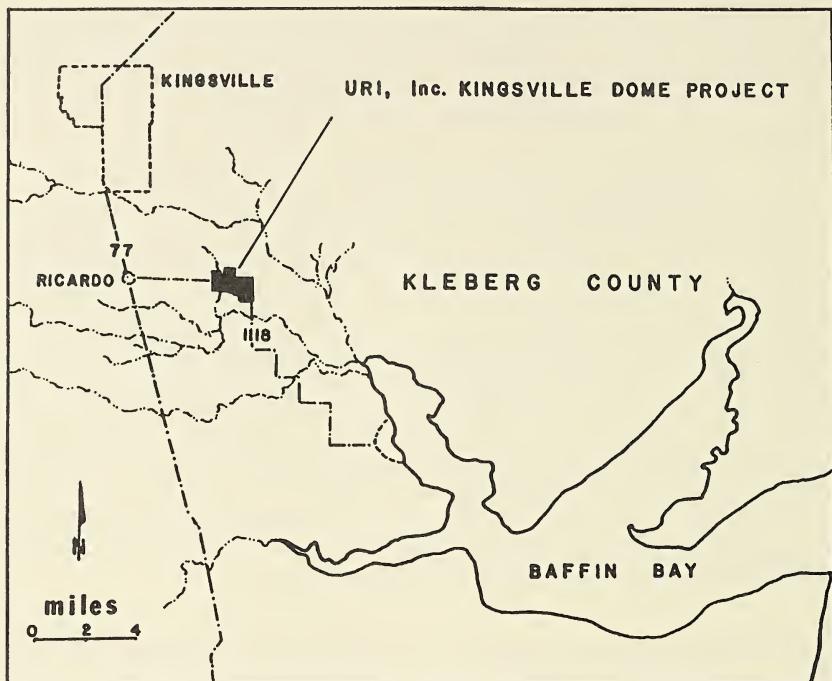


Figure 1. Location map of the Kingsville Dome uranium deposit.

In 1987, the Texas Water Commission, now the Texas Natural Resource Conservation Commission, approved Uranium Resources, Inc. (URI) application for solution mining and issued permits both for the mining of uranium and for the disposal of waste solutions by deep well injection into the Oligocene upper Frio Formation. The Texas Department of Health in 1987 issued a radioactive material license for an area of the Kingsville Dome which covers 28.239 hectares (69.78 acres). URI began *in situ* leach uranium mining operations in sediments of the Goliad Formation in September of 1987.

GEOLOGY OF THE GO利亚德 FORMATION

Stratigraphy.—The Goliad Formation lies above the Miocene Fleming Formation and below the Pleistocene Lissie and Beaumont Formations. Tedford et al. (1987) assigned it a late Miocene to early Pliocene age based on fossil mammals. The Goliad Formation as used in the present study is equivalent to that described by Plummer (1933), Solis (1981)

and Hoel (1982). Plummer (1933) subdivided the Goliad Formation into three members, the Lapara (lowest), the Lagarto Creek (middle) and the Labahia (highest). The Lapara Member consists of conglomerates, cross-bedded sands and calcareous clays which crop out at Lapara Creek in Live Oak County. The Lagarto Creek Member is red to pink calcareous clay and is exposed at Lagarto Creek in Live Oak County. The Labahia Member crops out at the San Antonio River along Mission LaBahia in Goliad County and consists of conglomeratic sandstones, sandstones and calcareous clays. In Kleberg County, the Goliad Formation occurs only in the subsurface and consists mostly of unconsolidated, fine and coarse-grained calcareous sands and sandstones interbedded with lenses of cemented sandy and calcareous varicolored clays (Shafer & Baker 1973). At the Kingsville Dome, the Goliad Formation consists of alternating gravelly sands and muds. These sands and gravels of the Goliad Formation contain ore deposits of secondary uranium minerals geochemically precipitated by ground water in the interstices of these clastic sediments.

Structural geology.—Structural maps of the base and top of the Goliad Formation show the Goliad dipping eastward with a gradient of 15 to 20 ft/mile (2.8 to 3.8 m/km) (Arredondo 1991). Several fault systems are present in subsurface in the Kingsville Dome area (Sams 1970). The Santa Gertrudis fault is one of the major faults which has affects the structural position of strata from the deep subsurface up to the Fleming Formation and this northwest trending fault displaces about 1400 ft (427 m) of sediment in the Frio Formation (W. Nollkamper, pers. comm.). Although there is displacement of the Goliad as shown by marker beds in well logs from oil and gas wells, the location of the Santa Gertrudis fault could not be accurately determined in the study area (Arredondo 1991). Faults which are known to displace deeper beds have been presented on a fault map, but were not delineated on the structure maps or cross-sections of the Goliad Formation (Arredondo 1991).

Petrology and petrography of sandstones.—Thin section analysis reveals that sediments of the Goliad Formation from the Kingsville Dome uranium deposit are primarily litharenites (Folk 1974). Thirty-two thin sections with concentrations of uranium ranging from 51 to 6200 ppm were examined. Sands at the Kingsville Dome contain sedimentary, metamorphic and volcanic rock fragments, and mineral grains that include quartz, calcite, K-feldspar, chert, clay and uranium. The distribution of quartz, feldspar and rock fragments plotted in Figure 2 shows the most common lithic fragments are sedimentary, with carbon-

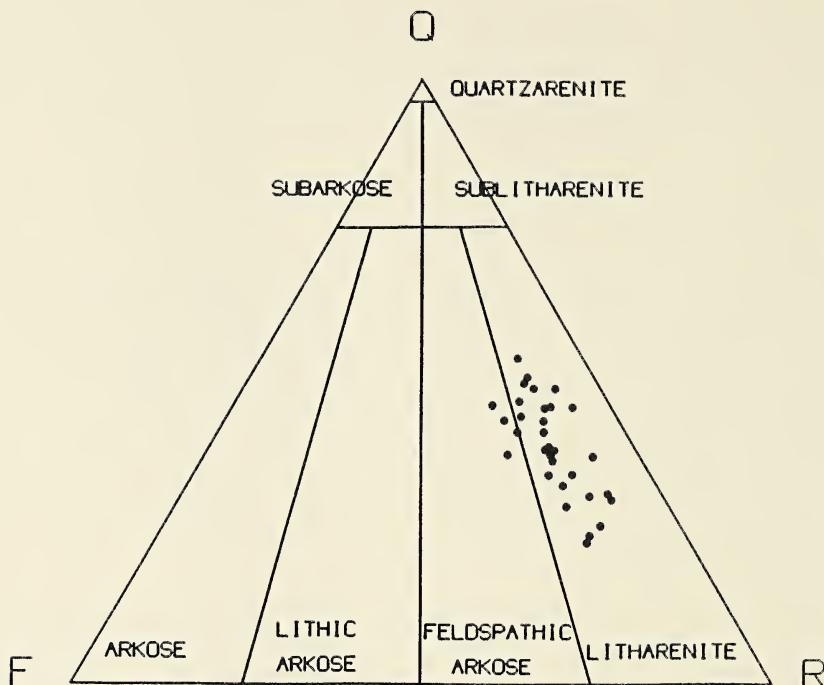


Figure 2. Quartz(Q) - Feldspar(R) - Rock fragment diagram for sandstones of the Kingsville Dome uranium deposit.

ate rock the most abundant type (Arredondo 1991). Petrographic examination of the 32 thin sections and Scanning Electron Microscopy (SEM) analysis of 10 core chips reveal that the Goliad sandstones have moderate to high intergranular primary porosity of 24 to 42%, and are poorly to moderately well sorted (Arredondo 1991).

Mineralogy.—Goliad sediments in the Kingsville Dome area are friable, dark gray, thinly laminated, fine to medium grained, calcareous quartz sand and silt with minor amounts of chert, K-feldspar, volcanic rock fragments, pyrite, marcasite, leucoxene, pyrite and marcasite intergrowths, Ca-montmorillonite, gypsum and traces of plagioclase, kaolinite, metamorphic rock fragments, mica, chlorite and barite. Quartz constitutes 14 to 30% of the framework grains, and many quartz grains have clay coats, calcite overgrowths, and clay coats with calcite. K-feldspar makes up 3 to 10% of the framework grains, and plagioclase occurs in trace amounts. Opaque minerals make up from less than 1 to 5% of the Goliad samples. Leucoxene is present as milky white sub-

micron masses associated with pyrite and is associated with uranium in sulfidized detrital ilmenite and pyrite after ilmenite pseudomorphs. This alteration also occurs commonly in uranium deposits in Live Oak County, Texas (Bomber et al. 1986). Opaque minerals commonly occur in the volcanic fragments as iron disulfides and titanomagnetite and some are enclosed with carbonate cement. Carbonates are micritic fragments of sparry calcite at the edges of clay clasts and microsparite.

Iron sulfide (as marcasite overgrowths) occurs as poikilotopic cement around pyrite and ilmenite grains. Most framework grains contain some diagenetic montmorillonite clay. Authigenic microsparite, micrite and acicular gypsum occur on the quartz and detrital clay grains. Gypsum occurs as elongated lath-like radiating crystals and are observed on Ca-montmorillonite substrates with micrite and microsparite cement overgrowths. Diagenetic barite crystals grew as elongate interlocking tabular crystals on quartz grains, along with carbonate cement overgrowths.

Five bulk mineral X-ray diffraction analyses for two core samples reveal quartz, calcite and Ca-montmorillonite clay as the major mineral components (Arredondo 1991). Diagenetic minerals such as calcite, gypsum and barite are associated with the thin coats of authigenic Ca-montmorillonite clay. Ca-montmorillonite is the major clay mineral that coats the framework grains, and kaolinite occurs in trace amounts. Kaolinite was not recognized in the petrographic and SEM analysis of the sediments, but was identified by X-ray diffraction (XRD) analysis. XRD analysis of the bulk minerals of the Goliad Formation revealed peaks with minor intensities corresponding to the diffraction patterns of uraninite (UO_2). Uraninite was identified by XRD in only one of ten samples investigated, and additional attempts to identify other uranium minerals by XRD were unsuccessful due either to their low concentrations or low crystallinity. Chemical analysis for uranium using visible light spectrometry shows that the highest uranium concentrations in the sediments are approximately 0.69% U_3O_8 . Such uranium concentrations are generally below the detection limits of the X-ray diffractometer (Huang 1978). Identification of uranium minerals in all of the clay size fractions was not possible with XRD, because the uranium was either sorbed onto clay minerals or was not crystalline. However, energy dispersive X-ray fluorescence analysis of the sample slides containing the clay fractions reveals the presence of uranium in the clay fractions. The uranium mineral is likely pitchblende since it occurs as amorphous phases, and the presence of fine crystallites suggests the presence of uranium ore minerals. The results of some studies of uranium deposits

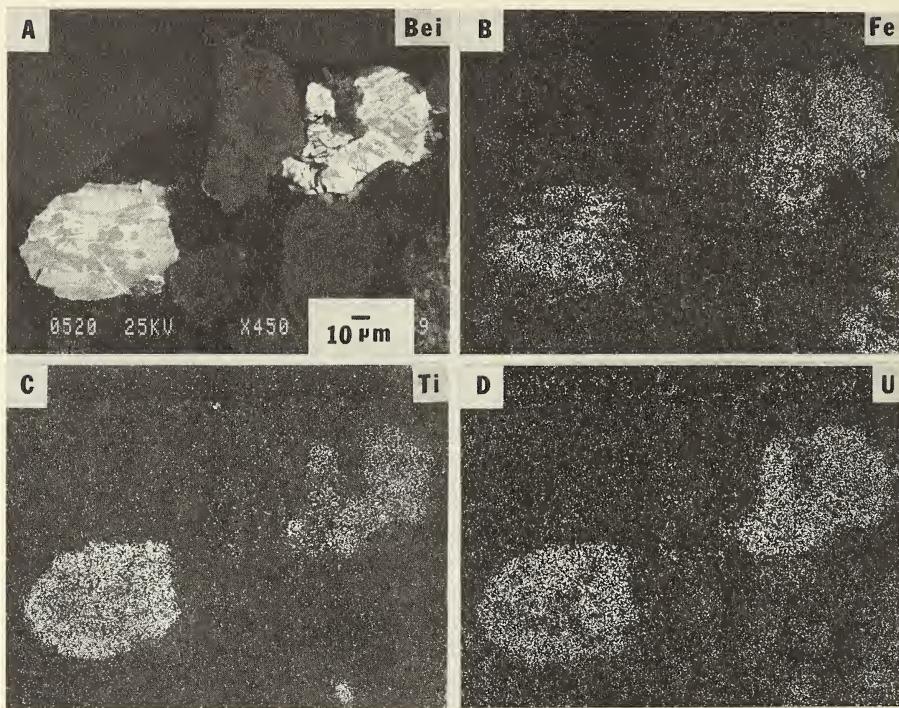


Figure 3. Composite of 4 SEM micrographs of core KVD-AA15-559 taken with a backscattering electron image (BEI) detector. A) shows 2 detrital grains that contain titanium, replacement iron disulfide (pyrite and/or marcasite) and uranium. Brightness in photos corresponds to the higher atomic masses. The brightest areas occur where titanium and uranium are present. The darker patches on the two grains contain iron sulfides. The electron distributions are presented for B) Iron, C) Titanium and D) Uranium. Original micrographs are 3.5 by 4.5 in. with magnification of 450 times. Bar = 10 μ m.

in South Texas using analytical electron microscopy (AEM), reveal that some uranium in the clays occur as tiny spherules which contain extremely fine crystallites of uranium bearing minerals that are approximately 0.1 microns in length (N. Guven, pers. comm.). Electron density microphotographs of heavy minerals using the SEM show that iron, titanium, uranium, sulfur and calcium are the most commonly occurring elements which are associated with the uranium ore minerals (Figure 3). The electron density microphotographs of heavy minerals show that uranium commonly occurs with titanium. The uranium compounds which commonly occur in association with Fe-Ti oxide minerals, pyrite and marcasite are amorphous. Uranium is associated with replacement iron disulfide and titanium oxide minerals.

Authigenic minerals in the uranium bearing samples are Ca-montmorillonite, pyrite, marcasite, sparite, microsparite, micrite and titanium oxide. Pyrite and marcasite have replaced detrital ilmenite or titanium magnetites in some samples of heavy mineral grains. These iron sulfides are occasionally found as thin, laminations in sediments from the reduced ore zones.

Occurrence of uranium at the Kingsville Dome.—The uranium at the Kingsville Dome deposit occurs within the interstices of the sands of a bedload fluvial system (Arredondo 1991) in the Goliad Formation. Mineralization developed in the form of the "classic roll-front" which contains hematite in the unaltered zone, limonitic minerals in the altered tongue, a reduced mineralized zone, and a reduced barren zone (Granger & Warren 1974). The mineralized fronts formed when ground water, enriched with uranium, invaded a zone that had been reduced by methane and hydrogen sulfide gases. The gaseous reductants migrated into the Goliad through faults from deeper hydrocarbon reservoirs. These geochemical conditions are considered by many investigators (Reynolds & Goldhaber 1978; Goldhaber et al. 1978; Galloway & Kaiser 1980; Harshman 1974) to be responsible for the formation of many ore deposits which occur both in the Ray Point, Texas District and the South Texas Uranium Districts. Mineralization of uranium deposits as roll-fronts is common especially in the Powder River Basin and Gas Hills Uranium Districts in Wyoming, and the Crownpoint District and Churchrock Uranium District in New Mexico (R. Clement, pers. comm.). However, the reductants in those areas are not from fault related methane and H_2S gases as in the Goliad. In the Powder River District, the reductant was from humate released from organic material in tuffaceous beds. In the Gas Hills district, ores were formed by gaseous reductants that emerged from underlying unconformities. Some uranium ore deposits have ore that has been redistributed since primary mineralization. For example, the uranium ore at Crownpoint and Churchrock Districts was initially deposited in humate masses as pods, but subsequently was redistributed by oxidizing meteoric ground water which formed roll-fronts. These oxygenated waters migrated when the regional hydraulic gradients were increased by an uplift during the Tertiary period (R. Clement, pers. comm.).

At the Kingsville Dome the roll-fronts form a mineralized area which has been delineated by exploration and development drilling. The uranium fronts trend northwest-southeast and occur on the southwest flank of the Kingsville Dome. This deposit formed as multiple roll-

fronts, each approximately 30 to 70 ft (9.14 to 21.33 m) wide, in the major sand horizons of a confined aquifer. Although the precise age of the uranium deposit at the Kingsville Dome is unknown, estimates based on measurement of the disequilibrium of uranium and its daughter products made by Princeton Gamma Tech, using high resolution spectroscopy, is between 450,000 and 159,000 years. The authigenic minerals associated with the uranium ore are iron disulfide (as replacement pyrite), marcasite, sparite (as marcasite and pyrite intergrowths) and microsparite which is attached on Ca-montmorillonite clay. Titanium occurs as titanium oxide and was found associated with uranium and replacement iron disulfide minerals which are common in South Texas deposits (Goldhaber et al. 1978; Childs 1981; Reynolds & Goldhaber 1983). Some uranium at the Kingsville Dome is non-crystalline and is adsorbed on the surfaces of thin authigenic Ca-montmorillonite clay coats on quartz sand grains. Uranium is also associated with detrital iron-titanium oxide minerals that have been replaced by iron disulfide minerals and titano-magnetite in volcanic fragments. Euhedral and anhedral uranium and titanium minerals were identified using polished thin sections.

A MODEL FOR URANIUM MINERALIZATION AT THE KINGSVILLE DOME - GEOCHEMISTRY AND PARAGENESIS

Mineralization of sediments at the Kingsville Dome resulted from geochemical processes involving acid-base (hydrolysis), ion exchange and oxidation-reduction reactions. The paragenetic sequences of mineralization at the Kingsville Dome are summarized in Figure 4.

Carbon dioxide bearing waters infiltrated the semi-confined aquifers of the Goliad Formation and formed carbonic acid which dissociated and formed bicarbonate at a slightly alkaline pH (Drever 1982). Hydrolysis of glass shards in volcanic tuffs of the Catahoula Formation occurred prior to uranium mineralization within this area of the Goliad and released H^+ , Na^+ , Al^{3+} , Si^{4+} , K^+ and Ca^{2+} . Uranium in the volcanic tuffs was also dissolved by naturally oxidizing water. The Oakville Formation is also a likely source for the uranium within the Goliad because, (1) uranium deposits are considered to occur updip of the study area (Galloway et al. 1982), (2) it is older than the Goliad, and (3) it contains ground water in areas with moderate transmissivity in a direction up-gradient from the study area (Galloway et al. 1982). The alteration of minerals in terrigenous sediments increased the ionic activity of the ground water. Surface water infiltrated into the

PARAGENETIC SEQUENCE AT THE KINGSVILLE DOME DEPOSIT

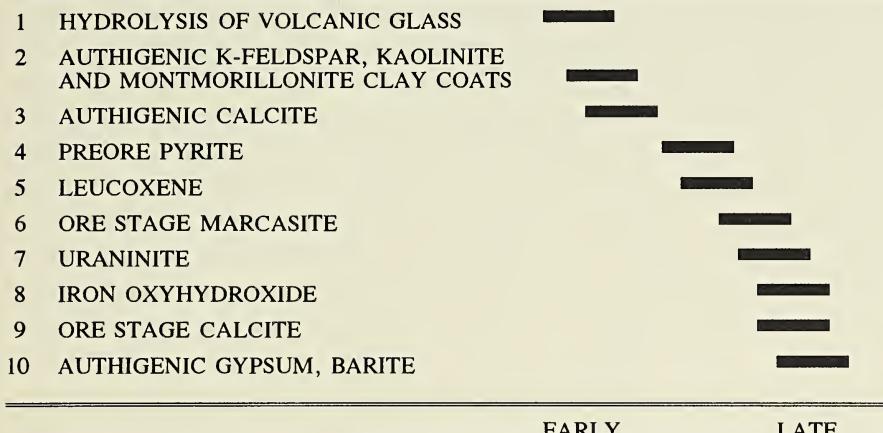


Figure 4. Paragenetic sequence of mineral formation at the Kingsville Dome uranium deposit.

unconfined portion of the Goliad aquifer and subsurface flow of ground water migrated down dip by a paleohydrologic gradient to the east. Calcium montmorillonite probably formed by hydrolysis of plagioclase (Hem 1989) in which the anorthite component of plagioclase was altered to montmorillonite. Kaolinite also formed from the hydrolysis of plagioclase and authigenic K-Feldspar formed from dissolved silica and potassium and aluminum. The increased concentrations of aluminosilicates in the ground water also precipitated montmorillonite on quartz framework grains. Authigenic calcite formed by acquiring calcium by ion exchange with sodium from the montmorillonite clays.

The uranium was transported by advection of ground water along the highest conductive flow paths of the major sand horizons as $\text{UO}_2(\text{CO}_3)_2$ or $\text{UO}_2(\text{CO}_3)_3$ complexes (Langmuir 1978). An increase in pH allowed uranyl to complex with bicarbonate and form a uranyl dicarbonate or uranyl tricarbonate (Langmuir 1978). Iron was also adsorbed on montmorillonite clay (Drever 1982). No halo or morphology of iron oxyhydroxide was recognized in petrographic analysis of ore zone samples.

Hydrogen sulfide from deeper formations entered the Goliad through faults and reduced the oxygen levels in the meteoric ground water. Detrital ilmenite grains decomposed in the reduced environment which was produced by the methane and hydrogen sulfide. Ferrous iron was

liberated (Morad & AlDahan 1986) to combine with sulfur and form the pre-ore stage pyrite and titanium dioxide (leucoxene). Leucoxene also formed from the Ti magnetite from altered volcanic sediments. There is no evidence to indicate more than one ore-stage sulfidization event in the relatively young Kingsville Dome ore deposit. Precipitation of ore-stage marcasite on pre-ore pyrite at the leading edge of an alteration tongue has been documented by Reynolds & Goldhaber (1983) as characteristic of some roll-type deposits in South Texas. These conditions also existed at the Kingsville Dome, where detrital Fe-Ti oxides and Ti-magnetites within the mineralization fronts were altered by hydrogen sulfide gasses to form marcasite in the replacement of pyrite. Altered ilmenite occurs as leucoxene (TiO_2) and exsolution lamellae of relic ilmenite grains are also present. Dimanche & Bartholomé (1976) and Morad & AlDahan (1986) referred to studies in which investigators recognized the alteration of ilmenite to anatase and rutile. Adams et al. (1974), Reynolds et al. (1977), Childs (1981) and Claassen (1981) documented similar observations in which detrital ilmenite and Ti-magnetite alters to form leucoxene in chemically reducing conditions. Similarly, Galloway (1982) has also recognized that uranium mineralization in the South Texas uranium district is associated with pyrite, marcasite and titanium oxide minerals, with precipitation of uranium minerals by oxidation-reduction reactions.

Uranyl dicarbonate was adsorbed onto montmorillonite and onto leucoxene which had formed from previous alteration of relic ilmenite and volcaniclastics. Uranium was likely precipitated in voids that were created by decomposition and dissolution of ilmenite during the pre-ore sulfidization event. Uranium was identified as a coating, which had adsorbed onto the large surface areas of very fine grained or amorphous titanium oxides (Arredondo 1991). Uranium as uranyl dicarbonate and hydrogen sulfide as $2HS^-$ reacted to precipitate uranium as uraninite (UO_2) in the mineralization front parallel to the iron redox front. Langmuir (1978) has suggested that the precipitation of uranium from uranyl tricarbonate occurs by the oxidation of HS^- to SO_4^{2-} , with ferrous iron oxidized to amorphous iron hydroxide. Langmuir further states the oxidation of FeS_2 , CH_4 and H_2 can precipitate the uranium from ground water and reduce the concentrations of dissolved uranium below detectable levels. Ghost roll-fronts that contain radioactive daughters of uranium are present, and remain in the barren oxidized zones approximately 15 to 30 m (50 to 100 ft) from the mineralized uranium fronts at the Kingsville Dome operations. Oxygenated meteoric ground water followed the paleohydrologic flow path which was induced

by a regional hydraulic gradient, and flowed into the zone of reduced ground water. Oxidizing meteoric ground water at the reducing-oxidizing interface prompted the oxidation of iron in the iron disulfides (pyrite and marcasite) to ferrous iron and formed iron oxyhydroxide. Uranium was dissolved, transported and reprecipitated a few tens of meters further down the ground water flow gradient. The oxidized alteration envelope formed after sulfur oxidized to form sulfate, and ferrous iron oxidized to form limonite. Iron and carbonate ions reacted with sulfur to form iron oxyhydroxide and sulfate and the ferric oxyhydroxides recrystallized to form hematite. Formation of ore-stage calcite was followed by gypsum and barite precipitated from reaction of Ca^{2+} and Ba^{2+} with sulfate produced by previous oxidation of iron sulfide.

SUMMARY

The Kingsville Dome uranium roll-front deposits formed when meteoric oxidized ground water enriched in uranium came in contact with ground waters reduced by methane and hydrogen sulfide gasses that migrated upward from underlying hydrocarbon reservoirs. The uranium most likely originated from leaching by meteoric ground water of uranium-bearing tuffaceous units in the Catahoula Formation.

Core samples show that Goliad Formation sediments are litharenites with 24 to 42% porosity. Sparite cement and micrite occur on the poorly cemented sand grains. Core analysis of ore sediments by X-ray diffraction methods indicates the major components are quartz, calcite and clay. Clay minerals in the clay size fraction are predominantly Ca-montmorillonite with lesser amounts of kaolinite. Iron disulfide minerals occur as both pyrite and marcasite in core samples from the roll-front. Ilmenite and Ti-magnetite comprise some of the other opaque minerals. Uranium minerals occur as an amorphous substance (pitchblende), and as uraninite, which are present only in the ore zone. SEM and EDS analysis reveals that uranium is adsorbed on thin authigenic Ca-montmorillonite clay coats on quartz sand grains, and is also associated with detrital iron-titanium oxide minerals and replacement iron disulfides. The diagenetic minerals which coexist with the uranium ore at the Kingsville Dome deposit are commonly associated with secondary uranium ore deposits such as those found in similar deposits in Texas, New Mexico, Colorado and Wyoming.

The deposit at the Kingsville Dome is similar to other uranium deposits in the South Texas Uranium District in that the roll-fronts are located in the sands which have the highest transmissivities (Arredondo

1991). The roll-fronts are confined to sandy beds bounded above and below by semipermeable clay lenses. The mineralization fronts which consist of multiple roll-fronts are located in a southeast-trending mineralized area and are similar in geometry to other South Texas uranium deposits. The uranium ore is in secular disequilibrium with its radioactive daughters because the deposit has moved with migrating ground waters and is estimated at between 450,000 to 159,000 years old.

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EVALUATION OF SOFTWARE GENERATED BY CODE GENERATORS

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Abstract.—Computer generated code was examined with respect to efficiency, using the McCabe Tool and also by manual examination of the C language code produced. Three segments of automatically generated code were chosen from existing Marshall Space Flight Center (MSFC) software. The complexity and error estimate tend to be overstated by the McCabe Tool for automatically generated. Additionally, the direct examination of the code found cases of inefficiency.

Traditional software development follows a cycle wherein the project phases of requirements definition, analysis, design, system construction and system testing are performed sequentially. In software engineering, as in manufacturing, the end product is improved when there is overlap between the phases. This is because feedback from those executing later phases may improve the work of those executing earlier phases, thus leading to a more coherent finished product. Computer Assisted Software Engineering (CASE) Tools, which automate the entire software development cycle, encourage the team engineering approach by allowing all developing files be shared among the various team members.

There are numerous studies, (Wietz 1992: Keyes 1992) which show that CASE Tools greatly facilitate software development. As a result of these advantages, an increasing amount of software development is done with CASE Tools. As more software engineers become proficient with these tools, their experience and feedback lead to further development with the tools themselves. In fact, new versions of software development programs appear with a frequency similar to those of operating systems and office application software. However, the correctness and efficiency of the actual code produced by the CASE Tools has not been widely studied. This investigation primarily concerns the efficiency of the produced code.

METHODS

Three existing code modules, ETO (Earth to Orbit Flight Software), ECLSS (Environmental Control and Life Support System) and PFMC

Table 1. McCabe analysis of matrix X 3.0 code.

Name of Module	PRMC			ECLSS			ETO					
	v(g)	ev(g)	# of lines	err est.	v(g)	ev(g)	# of lines	err est.	v(g)	ev(g)	# of lines	err est.
Main	8	1	249	3.54	3	1	9	0.13	3	1	34	0.11
Background	4	3	22	0.05	4	3	22	0.05	4	3	22	0.05
Error	6	1	27	0.11	6	1	27	0.11	6	1	27	0.11
External_Input	6	1	25	0.20	6	1	25	0.20	6	2	25	0.20
External_Output	4	1	28	0.16	4	1	28	0.16	4	1	28	0.16
Implementation_Term	43	11	189	1.75	43	11	189	1.75	43	11	189	1.75
Init_Sched	4	4	38	0.46	4	4	38	0.46	4	4	38	0.45
Scheduler	73	17	244	3.86	50	17	232	2.58	47	8	240	2.42
Signal_An_Error	2	1	9	0.03	2	1	9	0.03	2	1	9	0.03
fatal_err	12	1	33	0.23	12	1	33	0.23	12	1	33	0.23
Subsystem01	36	5	369	3.09	62	40	307	4.54	10	1	421	4.67
Subsystem02	8	1	105	0.52	7	1	57	0.41				10.18
Subsystem03	3	1	21	0.09	3	1	27	0.14				
Subsystem04	4	1	86	0.47				10.79				
Subsystem05	26	1	153	0.96								
Subsystem06	22	15	149	0.79								
Subsystem07	26	1	154	0.95								
Subsystem08	26	1	153	0.95								
Subsystem09	9	5	61	0.27								
Subsystem10	3	1	5	0.25								
Subsystem11	3	1	49	0.31								
Subsystem12	3	1	22	0.08								
Subsystem13	11	3	123	0.92								
Cvt_Float_Boolean	2	1	9	0.02								
Max	2	1	9	0.01								
Min	2	1	9	0.01								
Mint	2	1	8	0.03								20.11

(Pump Fan Motor Control), from Marshall Space Flight Center were chosen as representative examples (Schreur 1994). Two modules were produced with Matrix X version 2.3 using ADA while the third was produced with Matrix X version 3 using C. Future versions of Matrix X were to have C compilers only. Therefore, this investigation was done using C instead of ADA so all three modules were programmed in C using Matrix X version 3.0. The initial analysis was done with this C code. When the newest version of Matrix X became available, two of the three modules were reprogrammed using version 4.0. Some peculiarities in the code generated were common to both Matrix X versions 3.0 and 4.0.

The McCabe Tool, a program for testing and analyzing code, was used to generate flow charts and various metrics (McCabe 1976; Halstead 1977) for the modules. The metrics of interest here are the error estimate and the complexity measures, v(g) and ev(g). V(g) is the number of linearly independent paths and is based on the number of decisions plus one. While ev(g) is a measurement of the content of unstructured constructs and counts the number of decisions which

Table 2. McCabe Analysis of Matrix X 4.0 Code.

Name of Module	ECLSS				ETO			
	v(g)	ev(g)	# of lines	err est.	v(g)	ev(g)	# of lines	err est.
Main	6	1	19	0.05	1	1	19	0.05
Background	4	3	18	0.05	4	3	18	0.05
Error	7	1	30	0.13	7	1	30	0.13
External_Input	6	1	25	0.20	6	1	25	0.20
External_Output	4	1	28	0.16	4	1	28	0.16
Implement_Term	37	14	162	1.45	37	14	162	1.44
Init_Sched	4	4	35	0.34	4	4	35	0.34
Scheduler	58	17	383	5.06	49	17	238	2.31
fatalerr	13	1	32	0.23	13	1	32	0.23
Update_Out	4	1	25	0.14	1	1	12	0.03
PrintReal_C	7	3	16	0.10	7	3	16	0.10
Subsystem01	59	13	377	2.69	29	4	941	14.53
Subsystem02	5	1	69	0.26				
Subsystem03	2	1	42	0.12				
Subsystem04	3	1	60	0.57				

contain branches in or out. Listed in Tables 1 and 2, an examination of the error estimate showed that it is approximately proportional to the number of lines of code, and may not realistically estimate the likelihood of errors. The complexity measures depend on the number of variables and the number of branches in the code.

A manual examination of the machine generated C code revealed three characteristics which need a more complete evaluation. They all involved If or Switch statements.

The first of these is the use of a Switch statement having only one actual case in addition to the default case, as seen below. It is the logical equivalent of an If statement which should run faster than a Switch.

```
switch( ITSK ){
    case 1 : SUBSYSTEM01(); break;
    default : break;
}
```

The second is the termination, without a break, of the last case in a nested Switch structure. This then relies on a fall through to the terminating break of the Switch structure. In manual programming, this is bad form, since a modification which adds another case could lead to improper execution.

```
switch( TASK_STATE[NTSK] ){

    case IDLE :

        switch( TCB[NTSK].TASK_TYPE ){

            case PERIODIC :

                if( TCB[NTSK].START == 0 ){

                    READY_COUNT++;

                    ...

                }else{

                    TCB[NTSK].START= TCB[NTSK].START - 1;

                }

                break;

            case ENABLED_PERIODIC :

                ...

            case TRIGGERED_SAF :

                if( TCB[NTSK].OUTPUT == 0 ){

                    BUS_OFFSET[NTSK] = 15 - BUS_OFFSET[NTSK];

                    ...

                }

            }

        }

    break;

}

case RUNNING :
```

Table 3. Results of Timing Tests.

Time with empty For loop:	0.03 s.
Time with If (1) statement	0.03 s.
Time with If (0) statement:	0.03 s.
Time with If (ITSK) statement switching ITSK=1 and ITSK=0:	0.03 s.
Time with Switch (ITSK) statement with ITSK=true:	0.04 s.
Time with Switch (ITSK) statements with ITSK=false:	0.05 s.

The third is that the condition in several If statements was 1, as shown by the example below. This is the logical equivalent of an unconditional branch around the else portion, which becomes dead code.

```
if( 1 ){
    fprintf( fp, "YTIME      %5ld%5ld%5d%11s\n",
    YCOUNT-1+IUCNT, ICOL, IIMG, "(1P3E25.17) );
}else{ }
```

The relative efficiency of Switch versus If statements is compiler dependent but the CASE Tools choose a control structure without regard to efficiency. Thus the code is not optimized for efficiency. An If statement has higher complexity than an unconditional branch statement, and might be expected to execute slower.

To test the effects of the above examples on the efficiency of the code, loops written in Borland C++ version 4.0 containing If(1), If(0) and Switch statements with the variable ITSK = 1 and ITSK = 0 were timed. The loops were run through five million cycles, and the results of the timing are given in Table 3 below.

It was found that the If did not slow down the program execution. With the Switch statements, however, the execution time was increased, so the efficiency of this code was affected. This 33% increase in execution time for the structure would be important in real-time applications where timing is critical.

While the reliability wasn't studied directly, a few comments are in order. A statement such as If (1) clearly adds to the complexity measure, and influences the projected error rate as estimated by the McCabe Tool. It is a phantom complexity since it isn't really a branch and it shouldn't affect the reliability of the generated code. However,

the software is less readable and therefore more difficult to maintain manually. The use of a Switch instead of an If also adds to the complexity metric, and to the error estimate and renders the code less readable.

CONCLUSIONS

The use of Case Tools generates C code which has If statements and Switch statements which would not be in manually produced code. These statements made the code more complex, and therefore maintain manually, but only the unneeded Switch statement affected the efficiency of the code.

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**SMALL MAMMALS FROM CHOS MALAL,
NEUQUEN, ARGENTINA, BASED UPON
OWL PREDATION AND TRAPPING**

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Abstract.—A survey of the small mammal fauna of the Chos Malal region of western Argentina is presented. While this study was primarily based upon an examination of owl pellets, some limited trap data was available. The results of this study are discussed in context with other studies from this region of South America.

Resumen.—Se presenta un relevamiento de los pequeños mamíferos de la región de Chos Malal, del oeste de la Argentina. Mientras que este estudio se basó primariamente en el análisis de regurgitados de lechuzas, algunos datos limitados fueron obtenidos mediante trampeo. Los resultados de este trabajo se discuten en el contexto de otros estudios de esa región de América del Sur.

There is little available knowledge of the small mammal fauna of the Chos Malal area which is located in Chos Malal Department in northern Neuquén Province of western Argentina (Figure 1). Faunal lists from archaeological remains were given by Massoia (1987) for Chenque Haichol, Picunches Department which is approximately 135 km south of Chos Malal. Additionally, mammalian studies have been conducted mostly in the Patagonian-Subantarctic ecotonal areas located in the southern portion of the Neuquén Province and in the adjoining Río Negro Province (Pearson 1984; 1987).

Current information relative to the small mammal fauna of Neuquén Province has been based primarily on systematic studies focusing on specific taxa (Thomas & Saint Leger 1926; Hershkovitz 1962; Pearson & Christie 1985; Barros et al. 1990) and on the contents of pellets of owls and other raptors examined primarily from the southern areas of the province (Massoia & Pardiñas 1988b; Massoia 1988a; 1988b; Hiraldo et al. 1995). Furthermore, information on Patagonian small mammals has been recently updated (Monjeau et al. 1994; Pearson 1995).

Raptor pellets represent a valuable source of information for determining the composition of small mammal assemblages worldwide (Valente 1981; Contoli 1984; Massoia 1988b; Jones & Goetze 1991; Moreno & Barbosa 1992). This study was undertaken to determine the



Figure 1. Map of Neuquén Province, Argentina, showing the location of Chos Malal.

small mammal composition of the Chos Malal area of Argentina based upon analysis of barn owl pellets in connection with a limited amount of trapping results.

STUDY AREA

Dominant vegetation of the Chos Malal area in the vicinity of the Neuquén River is of a sparse cover of typical Monte Desert shrubs (*Larrea nitida* and *Schinus* sp.); also, there are rocky outcroppings in the vicinity with other types of vegetation, such as orophilous grasses and shrubs. This area is ecotonal between the Monte Desert and Patagonian biological sub-regions (Cabrera 1976) and it is biogeographically important as the type locality of two little known mammal species, *Akodon iniscatus nucus* and *Ctenomys emilianus* (cf. Barros et al. 1990; Reig et al. 1990; Pearson 1995).

Table 1. Prey composition of barn owl (*Tyto alba*) pellets from Chos Malal, Neuquén Province, Argentina.

TAXON	N	%
<i>Eligmodontia</i> sp.	127	45.4%
<i>Microcavia australis</i>	36	12.9%
<i>Akodon iniscatus</i>	26	9.3%
<i>Akodon molinae</i>	11	3.9%
<i>Akodon</i> sp.	2	0.7%
<i>Thylamys</i> sp.	17	6.1%
<i>Oligoryzomys longicaudatus</i>	14	5.0%
<i>Phyllotis xanthopygus</i>	13	4.6%
<i>Ctenomys</i> spp.	11	3.9%
<i>Reithrodont auritus</i>	9	3.2%
Sigmodontines (undetermined sp.)	7	2.5%
<i>Mus domesticus</i>	2	0.7%
Birds	3	1.1%
Insects	2	0.7%
TOTAL:	280	

METHODS AND MATERIALS

One hundred ten intact pellets, some fragmented pellets and pellet debris discarded by barn owls (*Tyto alba tuidara*) were examined during this study. Although accumulated during an undetermined period of time, this material was collected in March of 1988 near the banks of the Neuquén River and the ravines that surround the alluvial plain approximately 3-5 km upstream from the city of Chos Malal. Numerous cavities in the banks appeared to harbor owls and two barn owl specimens were found dead (apparently shot) in the vicinity.

The 110 intact pellets provided 209 prey items, with an additional 71 items recovered from the fragmented pellets and debris. A total of 280 prey remains were recovered (Table 1). Pellets were dissected and identifiable remains, such as skulls and chitinous insect parts were recovered. Small mammals were identified by comparison with field-collected specimens from the Chos Malal vicinity, Laguna Blanca National Park (Zapala Department), and owl pellet remains from Rinconada (Collón Curá Department) in Neuquén Province. Diagnostic characters from the literature (Hershkovitz 1962; Myers 1989; Pearson 1995) and museum reference specimens from the Museo Provincial de Historia Natural, Santa Rosa, La Pampa, Argentina were also used.

Additionally, a limited amount of trapping was conducted from 2 through 9 March 1988 (totaling 226 trap-nights) in an area of the alluvial plain along the Neuquén River. Snap traps were placed under

large dense shrubs of molle (*Schinus* sp.) and creosote bush (*Larrea nitida*), and in stands of salt-cedar (*Tamarix gallica*) and Pampas grass (*Cortadeira* sp.) along the watercourse. All prey remains examined and specimens collected during the course of this study are deposited with the holdings of the Museo Provincial de Historia Natural in Santa Rosa, La Pampa, Argentina.

RESULTS

The most abundant taxon found in owl pellets from Chos Malal was *Eligmodontia* sp. which accounted for 45.4% of the total number of prey items (Table 1). The genus *Eligmodontia* in Patagonia is currently undergoing review (Ortells et al. 1989; Kelt et al. 1991; Zambelli et al. 1992; Tiranti, in press). It is clear from cytogenetic studies that two species inhabit west-central Argentina. The distribution of *Eligmodontia morgani* seems to be correlated to the Patagonian biogeographic sub-region and *E. typus* is mainly distributed in the Monte Desert (Tiranti in press). As these species of *Eligmodontia* appear to be morphologically difficult to distinguish, it is yet to be determined which could be present and preyed upon by owls in Chos Malal.

Following in prey dominance was the small cavy *Microcavia australis* (12.9%). Most of these individuals were immature with recently erupted premolars, owing to the post-natal replacement of the deciduous premolars (Contreras 1964), and probably representing a seasonal resource for the owls. Other mammals identified, in descending order of prey abundance, were the Patagonian mouse *Akodon iniscatus nucus*, the mouse opossum *Thylamys* sp., the rice rat *Oligoryzomys longicaudatus*, the leaf eared mouse *Phyllotis xanthopygus* (a species generally associated with rock outcroppings), and the brush mouse *Akodon molinae*. Regarding the identity of *Thylamys*, the species in this area has been generally regarded as *T. pusillus* (cf. Ojeda 1989; Monjeau et al. 1994; Pearson 1995; Birney et al. 1996). However, there is increasing evidence that in fact two species of *Thylamys* (excluding *T. elegans*) are present in west-central Argentina (Birney et al. 1996). Nevertheless, no consensus has been reached, as Palma (1994) considered *T. pusillus* to be a Monte Desert and Chaco form; while *T. pallidior* which is found at higher elevations, is considered Andean. On the other hand, Birney et al. (1996) proposes that *T. pallidior* should be considered the Monte Desert form and *T. pusillus* as Patagonian.

Also preyed upon were the tuco-tucos. Two species are known to occur in the area, *Ctenomys haigi* and *C. emilianus* (cf. Thomas & Saint Leger 1926; Pearson & Christie 1985). These two species of gopher-like burrowing rodents are poorly known and difficult to distinguish using skeletal remains; species identification was not attempted. Chos Malal is one of very few localities where two species of tuco-tucos coexist (Thomas & Saint Leger 1926; Pearson 1984; Reig et al. 1990). The prey assemblage also included the rabbit rat *Reithrodont auritus*, the house mouse *Mus domesticus* (in very low numbers) which is a rare item in rural owl diets. Also found as prey were undetermined sigmodontine rodents, birds (one identified as *Phrygilus* sp.; Emberizidae) and insects (scarabid beetles).

Although it is not possible to ascertain the barn owls' foraging areas in Chos Malal, it is well known that open areas are preferred (Taylor 1994). In the present prey assemblage, *Eligmodontia* sp. is numerically dominant and one of its species is known to prefer areas denuded of vegetation (Ojeda 1989). On the other hand, species such as *Oligoryzomys longicaudatus* appear in low numbers as prey, but as inferred from trapping, may be abundant. This would indicate that the alluvial plain, or at least the areas with dense riparian vegetation, are seldom exploited by the owls. As in other owl pellet analyses of other arid areas of western Argentina (De Santis et al. 1988; Tiranti 1988; 1992), barn owls generally prey on most small mammals that inhabit an area, with the smallest-sized sigmodontine rodents being the most numerically represented. As in this study, *Eligmodontia* has been found to be dominant in prey assemblages in other localities of Neuquén and in other arid portions of western Argentina (Montalvo et al. 1984; Massoia & Pardiñas 1988a; Tiranti 1992).

As result of trapping in the alluvial plain, a total of 27 sigmodontine rodents were obtained. *Akodon iniscatus nucus* and *Oligoryzomys longicaudatus* were the most abundant species, the latter being restricted to the proximity of the watercourse in dense stands of salt cedar (*Tamarix gallica*) and Pampas grass (*Cortaderia* sp.). The systematics of *Akodon iniscatus nucus* has been recently reviewed (Barros et al. 1990), but little is known of its biology, especially reproduction. Of 15 specimens of *A. iniscatus nucus*, two were gravid females; one had five embryos with crown-rump lengths of 17 mm and the other with six embryos (20 mm crown-rump length). Two males had scrotal testes with active epididymides, denoting some late reproductive activity. Burrows of *Microcavia australis* and *Ctenomys emilianus* were also

observed. Those corresponding to the small cavies were located on the base of creosote bush and molle shrubs in the foothills of a sedimentary hill. The tuco-tuco burrows were located in fluvial sand dunes in the alluvial plain of the Neuquén River. A single female tuco-tuco specimen of *C. emilianus* was collected.

DISCUSSION

In general, the mammals reported in this study belong to widespread species (*Microcavia australis*, *Reithrodon auritus*), some belonging to the Patagonian (*Akodon iniscatus*, *Phyllotis xanthopygus*) and Monte Desert (*Akodon molinae*) faunas. Also included are species that occur along specific habitats in broad areas, such as *Oligoryzomys longicaudatus*, that at least in some portions of its distribution is found associated with mesic or riparian conditions (*Cortadeira selloana*, *Baccharis* sp.) along drainages and watercourses (Tiranti 1989).

Species of Subantarctic affinities that can be found farther south such as *Abrothrix longipilis* or *Loxodontomys micropus* (cf. Massoia & Pardiñas 1988a; 1988b; Pearson 1995) were not detected. Additionally, considering the reports of Massoia & Pardiñas (1988a), the vesper mouse *Calomys musculinus*, and the yellow-nosed mouse *Abrothrix xanthurhinus* could be expected to inhabit the vicinity of Chos Malal.

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THE PLIOCENE PROBOSCIDEAN *RHYNCHOTHERIUM*
(MAMMALIA: GOMPHOTHERIIDAE)
FROM SOUTH-CENTRAL NEW MEXICO

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Abstract.—A lower jaw of a proboscidean from the Sierra Ladrones Formation of the Santa Fe Group in south-central New Mexico shows diagnostic features of *Rhynchotherium* and can be tentatively referred to *Rhynchotherium falconeri* Osborn pending a much needed species-level revision of the genus. This proboscidean is consistent with associated mammals and suggests a late Pliocene (Blancan) age, not younger than 2.2 million years ago.

Today, the Rio Grande provides a master drainage to a chain of en echelon, down-faulted late Cenozoic basins that extend from southern Colorado through central New Mexico to western Texas. The antiquity of the Rio Grande as an axial trunk stream of the rift appears to date back to the Pliocene, about 3 to 4 million years ago. Fossil mammal specimens have been used to establish this age by providing direct biochronologic age control on strata deposited by the ancestral Rio Grande (Tedford 1981). One of the first such mammal specimens utilized in this process was a proboscidean jaw found near Socorro, New Mexico (Fig. 1) reported by Needham (1936). This jaw, identified as *Rhynchotherium*, has not been described or illustrated, nor has it been reinterpreted in the light of current mammalian biochronology. Furthermore, it represents the only record of the genus *Rhynchotherium* from New Mexico.

SYSTEMATIC PALEONTOLOGY

Class Mammalia

Order Proboscidea

Family Gomphotheriidae

Genus *Rhynchotherium* Falconer 1868

Rhynchotherium falconeri Osborn 1923

Referred specimen.—New Mexico Bureau of Mines and Mineral Resources (NMBMMR PS-59), right and left dentaries with crown bases of lower incisors, incomplete left m₂ and right m₂-m₃, and complete left m₃ partially erupted (Fig. 2).

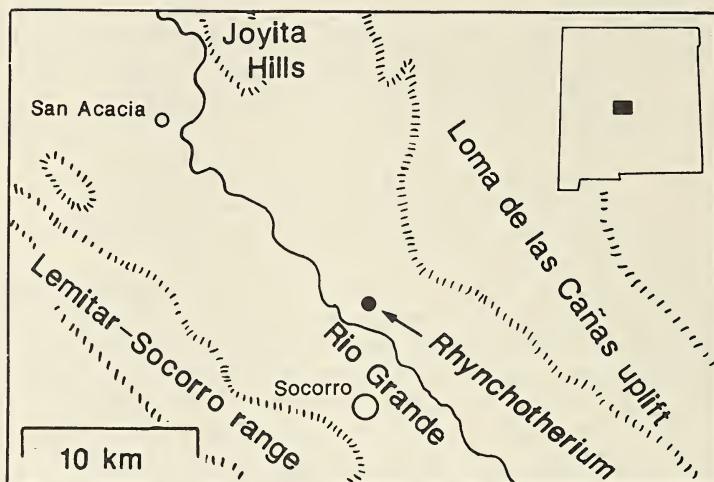


Figure 1. Map showing location of the *Rhynchotherium* site in the Arroyo de la Parida, Socorro County, New Mexico.

Horizon and locality.—Sierra Ladrones Formation, Santa Fe Group, Arroyo de la Parida, NW $\frac{1}{4}$ section 20, T2S, R1E, Mesa del Yeso USGS 7.5 Minute quadrangle, Socorro County, New Mexico.

Description.—The lower jaw has a sharply downturned spout-like symphyseal region with a convex ventral surface and a slightly concave dorsal surface. The angle between the horizontal plane of the cheek-tooth row and the downturned symphyseal region is approximately 30° . The symphysis extends back to just behind the anterior edge of the flange anterior to the m₂. The horizontal ramus is laterally concave anterior to the m₂ and its dorsal edge is a roughened flange that overhangs the lateral aspect of the ramus. Nine mental foramina are present in the lateral aspect of the horizontal ramus anterior to the m₂, three large and six small. The horizontal ramus under the m₂-m₃ is convex laterally and medially and not much wider than the molars. The ascending ramus is vertical, thin and plate-like, with a low, blunt coronoid process and a hemispherical condyle well above the plane of the cheek tooth row. The length of the lower jaws (tip of incisor alveolus to mandibular angle) is 735 mm; depth of the horizontal ramus below m₂ is 155 mm; and the height of the ascending ramus is 435 mm.

The two incisors are close together, procumbent and circular to slightly transversely flattened in cross-section. The incisor tips are

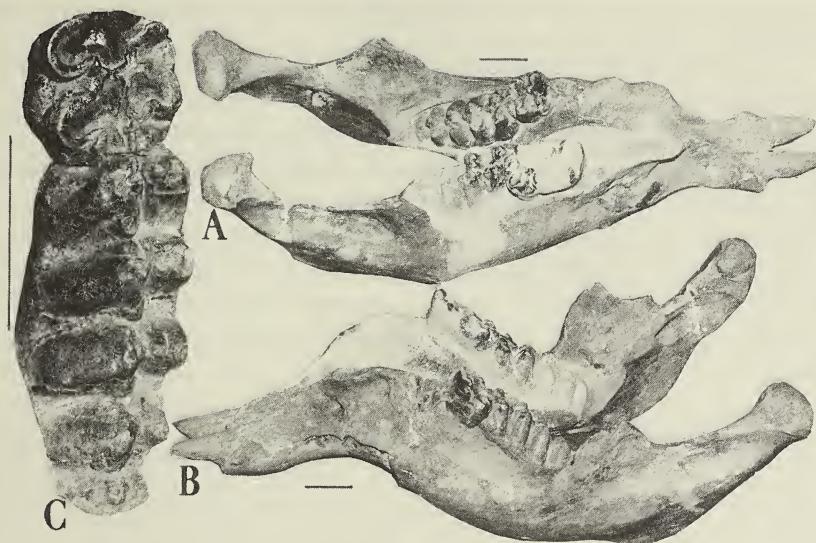


Figure 2. Lower jaw of *Rhynchotherium falconeri* Osborn from Arroyo de la Parida, Socorro County, New Mexico, in the collection of the New Mexico Bureau of Mines and Mineral Resources (NMBMMR PS-59). Occlusal (A) and left lateral (B) views of lower jaw and occlusal (C) view of left m₂-m₃. Bar scales = 100 mm.

missing and have been restored in plaster. This restoration of short, peg-like incisors clearly is incorrect, as comparison to other jaws of *Rhynchotherium* demonstrates (e.g., Osborn 1936: Fig. 478). There is no evidence of an enamel band on the lateral surface of the tusks, although both are heavily damaged. Most well-preserved lower tusks of *Rhynchotherium* possess a prominent lateral enamel band.

The left m₂ is mostly missing, and the right m₂ has been heavily restored in plaster. This heavily worn tooth has three lophids slightly canted so their lingual edges are anterior to their labial edges. The enamel on the m₂ is not ptychodont, there is a prominent posterior cingulid, and weak posterior pillars follow each lophid. Estimates of m₂ length and width are 125 mm and 71 mm, respectively.

The m₃ has 4.5 lophids and ptychodont enamel. The lophids are simple with a single pillar posterior to their labial edges (i.e., a single trefoil). The pillar is largest behind the first (anteriormost) lophid and smaller behind the others. The posteriormost lophid consists of two conulids. The tooth is still erupting and shows minimal wear on the first two lophids. Measurements of m₃ length and width are 185 mm and 74 mm, respectively. The width/length index of m₃ is 40.

DISCUSSION

The Socorro jaw embodies many of the diagnostic features of *Rhynchotherium*, particularly the deep, downturned symphysis. The m3 has 4.5 simple lophids and its width is 40% of its length (Frick 1933; Osborn 1936; Webb & Tessman 1968; Tobien 1973; Webb & Perrigo 1984). *Rhynchotherium* typically has a narrow enamel band on the lateral surface of the lower tusks. This enamel band is not evident on the Socorro tusks, although its absence may be related to their damaged condition. A mandible of *Rhynchotherium* from the late Pliocene of Arizona also lacks lateral enamel bands on the lower tusks (Miller 1990).

Webb & Tessman (1968:805) noted that "Much work remains to be done before the taxonomy of advanced rhynchotheres can be adequately sorted out." Tobien (1973) echoed this observation and divided the named species assigned by various authors into three groups: (1) large forms with heavy peg-like lower incisors that should be transferred to *Gomphotherium* (*Aybelodon hondurensis*, *Blickotherium blicki* and *Rhynchotherium tlascalae*); (2) species based on isolated teeth that may not belong to *Rhynchotherium* (*R. francisi*, *R. anguirivale*, *R. rectidens*, *R. shephardii* and *R. brevidens*); and (3) species based on mandibles that belong to the genus *Rhynchotherium sensu stricto* (*R. browni*, *R. edense*, *R. falconeri* and *R. simpsoni*). Not all subsequent workers have accepted Tobien's conclusions. For example, Webb & Perrigo (1984) assigned both *Blickotherium blicki* and *Aybelodon hondurensis* to *Rhynchotherium* (as *R. blicki*).

Nevertheless, Tobien's (1973) conclusions provide some guidance with which to identify the New Mexican proboscidean jaw. Clearly, this jaw displays features of *Rhynchotherium* and can be closely compared to Tobien's third group, species assignable without question to *Rhynchotherium*.

The type lower jaw of *Rhynchotherium simpsoni* Olsen 1957 from the late Hemphillian (early Pliocene) Bone Valley Formation of Florida differs from the New Mexican specimen in having a narrower and longer mandibular symphysis that is more sharply downturned (at an angle of almost 50°) and a wider m3 (see Olsen 1957; Figs. 1A & C). A specimen of *R. edense* Frick 1933 from the late Hemphillian Mt. Eden local fauna of California has a shorter and narrower m3 and more downturned symphysis (Osborn 1936:500, Figs. 473, 478G & 482C). The type lower jaw of *R. browni* Osborn 1936 of late Pliocene age from

San José de Pimas, Sonora, Mexico, is similar to the Arroyo de la Parida specimen in the overall conformation of the jaw, but differs in having a shorter and considerably broader m3.

The lower jaw of *Rhynchotherium falconeri* Osborn 1923 most closely resembles the New Mexican jaw (Osborn 1936: Fig. 468). Dental measurements are similar and both jaws have a moderately downturned and long anterior symphyseal process. Pending a much needed revision of the species-level taxonomy of *Rhynchotherium*, the New Mexican specimen is cautiously assigned to *R. falconeri*. In offering this conclusion, it should also be noted that the differences between *R. falconeri*, *R. simpsoni*, *R. edense* and *R. browni* are minor and might represent variation within a single species of *Rhynchotherium*. The similarity between several North American species of *Rhynchotherium* was also discussed by Savage (1955), who noted that a mandible of this proboscidean from the late Hemphillian Christian Ranch local fauna in the Texas Panhandle was comparable to *R. falconeri*, as well as *R. browni* and *R. edense*.

Cope (1893) reported two species of late Pliocene (late Blancan) proboscideans from Mt. Blanco, Texas, that have since been placed in *Rhynchotherium* by other authors. He referred a lower jaw with m2-m3 to *Tetrabelodon shepardii* Leidy 1871 and he described an isolated m3 as the holotype of *Dibelodon praecursor*. Osborn (1923) subsequently designated Cope's jaw of *T. shepardii* the holotype of *Rhynchotherium falconeri*. Dalquest (1975) compared the type m3s of *D. praecursor* and *R. falconeri* from Mt. Blanco and concluded that they represented the same species. His name combination for the Mt. Blanco *Rhynchotherium*, *R. praecursor*, has been used by many subsequent authors (e.g., Kurtén & Anderson 1980) for Blancan members of the genus. The proper name for the Mt. Blanco *Rhynchotherium* hinges on whether or not species based on isolated teeth can be confidently assigned to this genus. Clearly, *R. praecursor* (Cope 1893) is the oldest available name for a gomphothere from Mt. Blanco with a simple dental pattern; however, referral of this species to *Rhynchotherium* is somewhat problematic. Tobien (1973) did not mention *R. praecursor* in his review of *Rhynchotherium*, probably because the species was based on an isolated tooth that lacked most of the diagnostic characters of the genus. The only species Tobien (1973) definitively referred to *Rhynchotherium* were those in which the tusk-bearing downturned mandibular symphysis is preserved. Therefore, the New Mexican specimen is referred to *R.*

falconeri, the only undoubted Blancan species of *Rhynchotherium* that preserves the characteristic morphological features of the genus.

BIOCHRONOLOGY

The earliest record of the genus *Rhynchotherium* is the species *R. blicki* from the early Hemphillian (late Miocene, 7-8 million years ago) of Honduras and El Salvador (Webb & Perrigo 1984). In temperate North America, the temporal range of *Rhynchotherium* is from the late early Hemphillian (late Miocene, about 7 million years ago) to the late Blancan (late Pliocene, 2.2 million years ago) (Lindsay et al. 1984; Tedford et al. 1987). The earliest record of the genus outside of Middle America is *Rhynchotherium* cf. *R. euhypodon* from the late early Hemphillian Manatee Dam local fauna of Florida (Webb & Tessman 1968) and the youngest records are mandibles of *R. falconeri* (=*R. praecursor* after Dalquest 1975 and Kurtén & Anderson 1980) from the late Blancan of southeastern Arizona (Miller 1990), the Blanco local fauna of Texas (Dalquest 1975), and the Macaspahlt local fauna of Florida (Morgan & Ridgway 1987).

The *Rhynchotherium* site in the Arroyo de la Parida is in the Sierra Ladrones Formation of Machette (1978). As mapped by Cather (1996), the Sierra Ladrones Formation consists of extensively intertongued piedmont and axial river lithofacies. The *Rhynchotherium* site is in deposits of the axial river lithofacies. Presumably, other fossil mammals reported from the Arroyo de la Parida by Tedford (1981) came from this lithofacies as well. Indeed, teeth of the characteristic Blancan horse *Equus simplicidens* are known from NMMNH Locality 3310 which is in the axial river lithofacies in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ section 18, T2S, R1E, about 1.6 km northwest of the *Rhynchotherium* site.

Tedford (1981:1019) noted that fossil mammals found at Arroyo de la Parida are *Rhynchotherium*, *Stegomastodon*, *Equus simplicidens*, *E. cf. E. cumminsii*, *E. cf. E. scotti* and cf. *Capromeryx* sp. He concluded that, except for the occurrence of *Rhynchotherium*, this association is typical of late Blancan southwestern faunas. *Rhynchotherium falconeri* does occur in at least two other southwestern late Blancan localities, the Blanco local fauna in the Texas Panhandle (Osborn 1936; Dalquest 1975) and from a site in southeastern Arizona (Miller 1990). The association of *Rhynchotherium* with the Neotropical immigrant xenarthrans *Glyptotherium* and *Glossotherium* confirms that the Blanco local fauna is younger than 2.5 million years ago (Galusha et al. 1984).

Lindsay et al. (1984) placed the highest stratigraphic datum for *Rhyncotherium* at 2.2 million years ago, which is clearly late Blancan (e.g., Lundelius et al. 1987). This is equivalent to the Blancan V interval of Repenning (1987).

Thus, although *Rhyncotherium* is not typical of late Blancan mammalian faunas, it has several late Blancan records in North America. This study concludes that the *R. falconeri* jaw from the Sierra Ladrones Formation in New Mexico is consistent with a late Blancan age, not younger than 2.2 million years ago. It, and associated mammals, date axial river deposits of an ancestral Rio Grande near Socorro, New Mexico, as late Pliocene.

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We thank Virgil Lueth, curator of collections at the New Mexico Bureau of Mines and Mineral Resources, for the loan of the Arroyo de la Parida *Rhyncotherium* specimen and John Hawley for information on its provenance. Steve Cather allowed us to examine his unpublished geological map of the Meso del Yeso Quadrangle. Ed Frye and Mike O'Keeffe generously donated several important fossils from the Arroyo de la Parida area to the New Mexico Museum of Natural History and Science.

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**WATERBIRD UTILIZATION
OF A FRESHWATER IMPOUNDMENT
ON A COASTAL TEXAS WILDLIFE REFUGE**

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Abstract.—Avian utilization of a freshwater impoundment located within the San Bernard National Wildlife Refuge along the upper Texas coast was studied during 1990 and 1991. Forty-three surveys were conducted to determine species richness, relative abundance and habitat use. While more than 100 species were recorded, only 49 were sufficiently present to determine seasonality and habitat use. Utilization of the impoundment by nesting, migrant and overwintering species is also reported.

Due to the attraction of freshwater over saltwater as habitat for many species of waterbirds, managers of coastal refuges typically impound freshwater to increase waterfowl populations for hunting and also to provide for the habitat needs of a greater diversity of birds (Chabreck et al. 1974). Few measures of the success of this strategy are available and little data are available on natural coastal wetlands in Texas. This study was undertaken to determine avian utilization of a freshwater impoundment adjacent to an estuarine wetland. Objectives were to: (1) quantify bird-species richness, species composition, and avian seasonality in a coastal freshwater wetland, (2) examine habitat use by bird species in an attempt to explain patterns of diversity, and (3) document the success of an effort to attract waterbirds by means of a created freshwater wetland. These data should enhance the understanding of temporal and spatial distribution of waterbirds, facilitate evaluation of the success of restoration and management efforts, and provide baseline data useful in assessing environmental damage.

STUDY AREA

San Bernard National Wildlife Refuge which is located along the mid Texas Gulf coast near Brazoria was purchased starting in 1969 by acquisition of several small ranches used by wintering waterfowl. It now totals 9,900 ha in size. Because mineral rights remained with the original owners, a road was constructed in 1976 to a well-drilling site in the saline marsh. This road crossed several freshwater flowages and thus served as a partial dam. To prevent water from diverting eastward around the roadbed and into the adjacent estuarine wetland, the Refuge

constructed a small wing dam, resulting in the formation an 81 ha freshwater impoundment named Moccasin Pond. The borrow ditch is on the pond side of the dam, insuring some deep-water habitats even when the wetland basin dries completely. Because of the potential for drying due to low rainfall and high evaporation and transpiration in summer, water-control structures under the road typically are closed during late spring to hold water for nesting birds. Salinity ranges from 0 to 3 ppt, dependent upon volume (Weller et al. 1994).

During the study period, which was unusually wet, even very shallow open-water areas of Moccasin Pond supported dense stands of submergent plants, mainly bladderwort (*Utricularia* spp.) and common water-nymph (*Najas guadalupensis*). A small stand of Mexican water lily (*Nymphaea mexicana*) was located in the ditch at the eastern end of the pond. Extensive stands of southern cattail (*Typha domingensis*) occurred along this ditch and in deeper-water areas nearby, and common cattail (*T. latifolia*) occurred along upslope ditches where drying was common in early to mid summer. Dominant vegetation changed from more regularly flooded to drier areas in the following sequence: sea-shore paspalum (*Paspalum vaginatum*), saltmeadow cordgrass (*Spartina patens*), a mixture of spiny aster (*Leucosyris spinosa* = *Aster spinosus*) and sea ox-eye daisy (*Borrichia frutescens*), Gulf cordgrass (*S. spartinae*), patches of the water-tolerant shrub sesbania (*Sesbania* spp.), and groundsel-tree (*Baccharis halimifolia*) at the western pond margin (Weller et al. 1994).

METHODS AND MATERIALS

Because of the complex vegetation patterns and the risk of disturbance to large flocks of birds common in Moccasin Pond, it was not possible to establish census plots. Instead, surveys were made from a vehicle on the elevated impoundment road which encircles the pond, recognizing some potential bias against species of dense cover. A total of 43 surveys was completed in 1990 and 1991, ranging from one to six per month. To correct for this monthly variance, data on frequency of occurrence (i.e., number of times a species was seen on a survey regardless of the numbers of birds seen per observation) and abundance (i.e., actual numbers of individuals of a species counted at each sighting) are presented as means of all surveys for each month. Annual indices of frequency and abundance were calculated by summing monthly survey means to avoid the bias of differential seasonal survey effort.

To provide a basis for understanding differential use of plants in the freshwater pond, the most frequently observed bird species were tallied by the vegetation zones in which they were seen. The vegetation map of Moccasin Pond used for recording birds was based on aerial photos and plant surveys conducted on five line transects (Weller et al. 1994). A total of 36 vegetation or physical habitat categories was noted during this study, and these were pooled to 18 categories of plant taxa (seashore paspalum, cattail, Gulf cordgrass, saltmeadow cordgrass, willow, groundsel-tree, *Sesbania*, sedge, water lily, *Sagittaria* spp.), life forms (shrubs, trees, planted ryegrass, snags), physical features (water, mud, burned area), or structures (fences). Aerial feeders like swallows, surface feeders like gulls and terns, and raptors were recorded as "flyovers" and were excluded from habitat-use comparisons because they could not usually be associated with vegetation zones. Several closely related species created identification problems and were pooled in data analyses to avoid bias toward one species (after Weller 1994).

RESULTS

Species composition and seasonality.—More than 110 bird species were recorded during the surveys, but many were neotropical migrants observed only once or a few times. To provide sufficient records to assess seasonal and habitat use, only data for the 49 species or grouped taxa observed more than 10 times were analyzed (Table 1). Annual mean indices of frequency and abundance (Table 1) are highly correlated ($r=0.928$), but frequency data are less biased by extreme flock sizes characteristic of many waterbirds. Scientific names follow those of the American Ornithologists' Union (1983).

Bird species composition was typical of freshwater habitats, with 11 Ciconiiformes (bitterns, egrets and herons), 10 Anseriformes (eight ducks and two geese), and resident as well as migrant American Coots, Common Moorhens and Pied-billed Grebes. Unlike observations from other freshwater ponds near the coast, diving ducks (*Aythya* spp.) were rare, probably due to the shallowness of the area which rarely exceeded 40 cm except in ditches. Because this was a period of high rainfall, and mudflats were minimal during most the surveys, the only migrant shorebirds were species of flooded areas, yellowlegs and dowitchers. However, Black-necked Stilts and Killdeer (which tend to use small and drier habitat patches) were regular. Two Passeriformes (Red-winged Blackbird and Boat-tailed Grackle) dominated the breeding avifauna because of their social disposition and their adaptability to a wide range

Table 1. Birds of a freshwater impoundment at San Bernard National Wildlife Refuge ranked according to frequency from high to low. Breeding birds indicated by an asterisk. Vegetation categories number based on use by each taxon of 18 possible types.

Taxon	Cumulative Mean Frequency n = 9,654	Cumulative Mean Numbers n = 32,315	Vegetation Categories n = 9,419
Boat-tailed Grackle (<i>Quiscalus major</i>)*	471.8	587.6	15
Gadwall (<i>Anas strepera</i>)	398.2	1141.3	3
Green-winged Teal (<i>Anas crecca</i>)	313.6	1242.6	3
Northern Shoveler (<i>Anas clypeata</i>)	305.7	787.1	3
American Coot (<i>Fulica americana</i>)*	282.7	1347.3	8
Blue-winged Teal (<i>Anas discors</i>)*	277.4	1032.9	5
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)*	228.0	479.4	16
Common Moorhen (<i>Gallinula chloropus</i>)*	184.7	373.2	12
Pied-billed Grebe (<i>Podilymbus podiceps</i>)*	69.3	96.4	6
Great Blue Heron (<i>Ardea herodias</i>)	52.8	56.5	12
Great Egret (<i>Casmerodias albus</i>)	52.7	127.3	12
Mottled Duck (<i>Anas fulvigula</i>)*	48.8	109.8	6
Cinnamon Teal (<i>Anas cyanoptera</i>)	35.5	65.3	3
White Ibis (<i>Eudocimus albus</i>)	27.4	157.6	8
Snowy Egret (<i>Egretta thula</i>)	27.1	148.9	12
Cormorants (<i>Phalacrocorax auritus</i> and <i>P. brasiliiana</i>)	25.9	32.9	4
American Wigeon (<i>Anas americana</i>)	25.6	55.0	2
Tricolored Heron (<i>Egretta tricolor</i>)	25.0	34.1	11
Northern Pintail (<i>Anas acuta</i>)	23.9	38.6	1
Savannah Sparrow (<i>Passerculus sandwichensis</i>)*	22.1	42.0	10
Killdeer (<i>Charadrius vociferus</i>)*	20.3	23.0	4
Eastern Meadowlark (<i>Sturnella magna</i>)*	20.1	26.8	10
Black-necked Stilt (<i>Himantopus mexicanus</i>)*	18.6	26.8	7
Terns (<i>Sterna forsteri</i> and <i>S. hirundo</i>)	16.9	22.5	—
White-faced Ibis (<i>Plegadis chihi</i>)	15.5	123.5	5
Night-Herons (<i>Nycticorax nycticorax</i> and <i>Nyctanassa violacea</i>)	14.6	28.1	6
Northern Harrier (<i>Circus cyaneus</i>)*	13.8	13.8	—
Least Bittern (<i>Ixobrychus exilis</i>)*	11.9	15.2	6
Little Blue Heron (<i>Egretta caerulea</i>)	11.4	23.6	6
Mourning Dove (<i>Zenaida macroura</i>)*	11.2	20.3	7
Green Heron (<i>Butorides striatus</i>)	11.1	12.4	9
Eastern Kingbird (<i>Tyrannus tyrannus</i>)*	10.7	14.8	8
Greater White-fronted Goose (<i>Anser albifrons</i>)	9.2	59.1	4
Purple Gallinule (<i>Porphyrrula martinica</i>)*	9.1	10.8	10
Canada Goose (<i>Branta canadensis</i>)	8.2	1089.2	2
Tree Swallow (<i>Tachycineta bicolor</i>)	7.3	10.9	—
Other Blackbirds (<i>Euphagus</i> , <i>Molothrus</i>)	7.2	228.2	5
Black-shouldered Kite (<i>Elanus caeruleus</i>)	6.8	5.7	—
Barn Swallow (<i>Hirundo rustica</i>)	6.2	19.1	—
Warblers (esp. <i>Dendroica</i>)	5.9	13.9	2
Cattle Egret (<i>Bubulcus ibis</i>)	5.8	332.9	8
Yellowlegs (<i>Tringa melanoleuca</i> and <i>T. flavipes</i>)	5.4	7.8	5
Dowitchers (<i>Limnodromus griseus</i> and <i>L. scolopaceus</i>)	5.2	13.1	2
Caspian Tern (<i>Sterna caspia</i>)	5.0	5.3	—
Loggerhead Shrike (<i>Lanius ludovicianus</i>)	4.9	5.7	5
Dickcissel (<i>Spiza americana</i>)*	4.5	6.1	2
Laughing Gull (<i>Larus atricilla</i>)	4.3	5.3	—
Ring-billed Gull (<i>Larus delawarensis</i>)	4.1	6.2	—
Marsh Wren (<i>Cistothorus palustris</i>)*	3.5	5.8	2

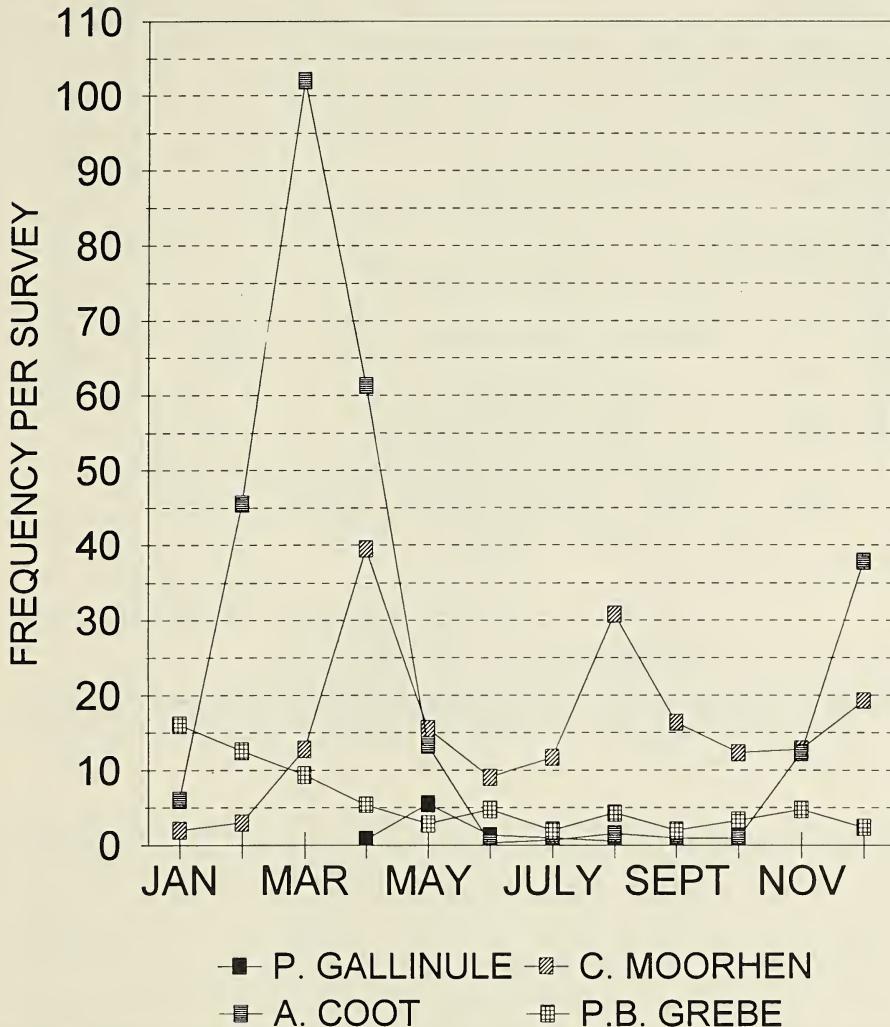


Figure 1. Frequency of occurrence (i.e., mean number of sightings per survey) of some resident waterbirds that nest in Moccasin Pond but also show migration peaks (American Coot and Common Moorhen), that breed and also show increased wintering populations (Pied-billed Grebe), and a breeding summer resident (Purple Gallinule).

of habitats (Table 1). Raptors included Northern Harriers (which seemingly nested in the area) and Black-shouldered Kites were present during fall migration and early winter.

Diverse patterns of seasonal use were comparable to those noted in adjacent estuarine wetlands, but often for different species (Weller 1994). Coots, gallinules and Pied-billed Grebes used the area year-round but typically had large migrant populations in spring and small nesting populations in summer (Fig. 1). After passage of a large spring

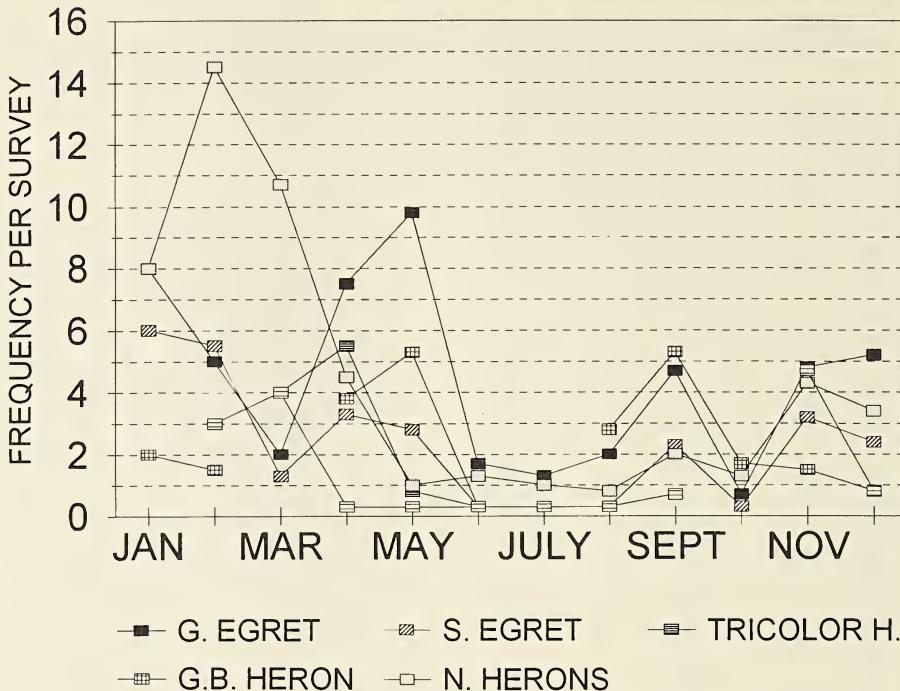


Figure 2. Frequency of occurrence (i.e., mean number of sightings per survey) of the more common egrets and herons that are present all year and feed or roost on the pond but breed elsewhere locally.

population, egrets and herons occurred in small numbers the remainder of the year (Fig. 2), but no nests or young were found. Some, like Great Blue Herons, exhibited erratic patterns of presence or absence suggesting nesting activities elsewhere, perhaps on offshore islands. Green Herons foraged in the area only briefly in spring and fall migration, whereas Least Bitterns arrived, nested and departed promptly thereafter (Fig. 3). Waterfowl had the largest populations which typically peaked during spring migration, with reduced levels in fall and winter (Fig. 4); only small numbers of Mottled Ducks nested regularly (Fig. 4). Blue-winged Teal are known to nest in the area, and although a few were present during the summer of this study, no nests or broods were noted.

Based on the 49 species for which the number of observations allowed analysis, species richness peaked in spring due both to migrants and the passage of large numbers of summer residents, dropped to its lowest in summer, recovered slightly in the fall migration, and increased again during early winter. Species richness by month from January to December was: 27, 37, 37, 40, 33, 21, 17, 25, 20, 22, 34 and 33.

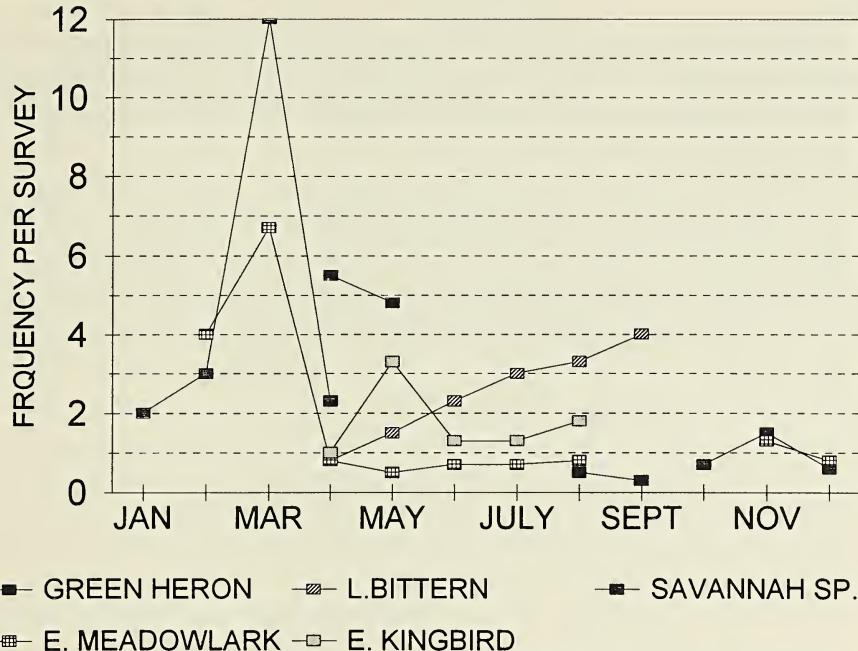


Figure 3. Frequency of occurrence (i.e., mean number of sightings per survey) patterns of short-term use for breeding (Least Bittern and Eastern Kingbird), wintering (Savannah Sparrow), or migration stopover (Green Heron). The Eastern Meadowlark occurs all year but in low numbers, especially in summer.

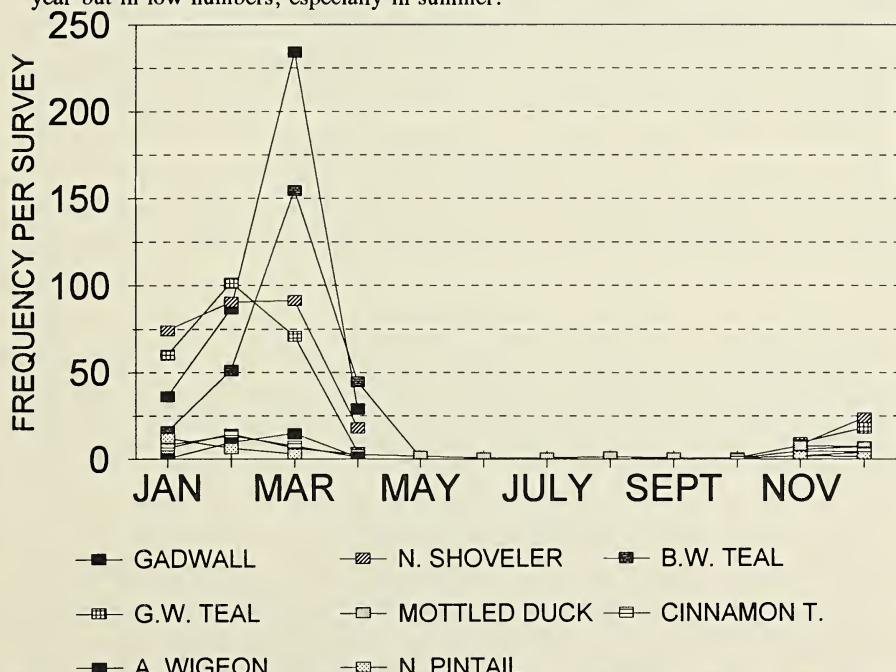


Figure 4. Frequency of occurrence (i.e., mean number of sightings per survey) patterns of use by the common migratory ducks, and the resident breeding Mottled Duck.

Thus, this constructed wetland provided habitat for a great variety of birds crossing or moving along the Gulf of Mexico, and maintained a diverse resident waterbird population during summer involving 15 to 18 species (Table 1).

Avian utilization of vegetation or structure.—Attempts to statistically correlate vegetation and distribution patterns at the species level were unsuccessful. This is probably due to the fact that the key habitat factor, water depth, could not be measured remotely at feeding or loafing sites. The most simple measure of habitat used was the number of plant categories in which birds were observed (Table 1). Ducks and other swimming waterbirds typically used three vegetation types: flooded seashore paspalum, open water and cattail. Seashore paspalum provided a rich source of seeds but also appeared to provide a suitable substrate containing invertebrates. Adjacent open-areas contained submergent plants suitable as food for herbivores such as Gadwall and American Wigeon. The Mottled Duck utilized more diverse habitats (six) and often drier sites than wintering ducks, which reflects an observed preference for isolation in small pools. Egrets and herons used a much wider range of habitats (usually six to 12 categories), presumably because they selected feeding sites by water depths and prey location rather than plant species. The shallow-marsh passerines (Boat-tailed Grackle, Red-winged Blackbird) used the most diverse range of habitat categories (15 and 16, respectively). Marsh Wrens (along with Least Bitterns) primarily utilized the more robust cattail, while migrant warblers and nesting Eastern Kingbirds utilized the scattered willow trees (*Salix* sp.) along the borrow ditch. Savannah sparrows selected generally drier habitats of 10 categories, and Dickcissels were the only species to regularly use the upland shrub area dominated by *Baccharis*.

DISCUSSION

Managers of coastal wildlife areas have long recognized the importance of freshwater as an attractant to wintering waterfowl (Palmisano 1972) and have used freshwater impoundments to enhance coastal areas for ducks (Chabreck et al. 1974, Morgan et al. 1976). Vegetation and water patterns also are known to influence waterbird species composition and diversity, although observations vary regionally or by wetland type (Weller & Fredrickson 1973; Craig & Beal 1992). Water depth is recognized as especially important in dictating the presence and distribution of wintering waterbirds (Burger et al. 1984; Colwell & Dodd 1995). Observations reported in this study tend to

confirm these generalizations, and elucidate some specific requirements for selected species. In comparing the species composition of this area with the adjacent estuarine complex (Weller 1994), ducks and other swimming waterbirds were much more abundant, and the presence of woody vegetation attracted some passerines not evident in the grassy vegetation. Although observations on habitat use were too general to isolate features essential to individual species, the commonality of habitat use and the sociality of many diverse species was evident. Differential food use presumably reduces competition, making high concentrations of mixed species possible.

While this enhanced wetland was less than 15 years old, it attracted a typical complement of freshwater birds and served neotropical migrants as well. Few data are available for coastal Texas; however, small ponds near Kingsville supported many of the same birds with high species richness (Briggs & Everett 1983). Similar bird species also were among those noted on the Welder Refuge near Sinton, Texas (Cottam & Glazener 1959; White & James 1978).

It is apparent that the success of wetland restoration efforts can be of value in offsetting wetland losses along the coast, but success would be influenced by exact position on the Gulf, water regimes, and adjacent habitats that attract birds. Further data from natural freshwater wetlands would enhance the capability to manage for suitable wetland attributes and better assess the success of enhanced, restored or created wetlands.

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We wish to express our sincere appreciation for the diligent efforts of technicians D. Oubari and S. Peck who entered the data into computer files. The interest, cooperation, and financial support of U.S. Fish and Wildlife Service staff are gratefully acknowledged: R. Bisbee, J. Crabtree and M. Lange of the Refuge Division and J. Haskins of the Southwest Region Migratory Bird Program. Additional support came from the Caesar Kleberg Chair in Wildlife Ecology at Texas A&M University.

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GENERAL NOTES

NOTEWORTHY RECORDS OF TWO SPECIES OF *MYOTIS*
(CHIROPTERA: VESPERTILIONIDAE)
FROM NORTHEASTERN MEXICO**Arnulfo Moreno-Valdez***Department of Wildlife and Fisheries Sciences, Texas A&M University
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Range extensions are reported for the distributions of the cinnamon myotis (*Myotis fortidens*) and for the Yuma myotis (*M. yumanensis*) in México. Specimens are deposited with the holdings of the Texas Cooperative Wildlife Collection (TCWC) and the Universidad Autónoma de Nuevo León (UANL).

The cinnamon myotis is known to be distributed from the Pacific Coast of Guatemala, northward through the Isthmus of Tehuantepec to southern Sonora and central Veracruz (Dickerman et al. 1981; Hall 1981). Three male specimens (TCWC 38816, 38817, 40129) and a single female (TCWC 40130) of *Myotis fortidens* were collected in the state of San Luis Potosí on 18, 19 and 20 May 1981 at 1.6 and 5.6 km west of Chantol, Rancho Pago Pago. This locality extends the range of *M. fortidens* approximately 475 km NW from the nearest recorded locality on the east coast of México (20 km WNW of Piedras Negras, Veracruz) by Hall & Dalquest (1950). External and cranial measurements (mm) of two males (TCWC 38816, 38817) are as follows: total length, 92, 89; length of tail, 44, 42; length of hind foot, 7, 9; length of ear from notch, 13, 15; length of forearm, 37.4, 37.5; greatest length of the skull, 15.1, 14.9; zygomatic breadth, 9.8, —; mastoidal breadth, 7.5, 7.4; breadth of braincase, 7.1, 6.8; interorbital breadth, 4.0, 3.9; length of maxillary toothrow, 5.5, 5.5; breadth across upper canines, 4.1, 4.0; intermaxillary breadth at M₃, 6, 6; greatest length of mandible, 10.9, 10.4. One male specimen (TCWC 38816) had testes 5 mm long.

The yuma myotis is distributed from British Columbia southward through the western United States to central México (Hall 1981). Two female specimens (TCWC 1959, 1960) and two males (TCWC 1961, 1962) of *Myotis yumanensis* collected on 20 June 1941 at 20 km N, and 20 km NW of Montemorelos, respectively. These specimens represent the first record of this species in the Mexican state of Nuevo León.

This locality extends the range of *M. yumanensis* approximately 170 km SW from the nearest recorded site (Starr County, Texas) by Schmidly (1991). External measurements of two females (TCWC 1959, 1960) and two males (TCWC 1961, 1962) are as follows: total length, 82, 85, 80, 75; length of tail, 35, 35, 35, —; length of hind foot, 9.0, 9.0, 8.0, 7.2 (dry); length of ear from notch, 12, 12, 11, 10 (dry); length of forearm, —, 34.4, 34.2, 33.1. Cranial measurements of two females and one male (TCWC 1961) are as follows: greatest length of skull, 13.7, 13.7, 13.6; mastoidal breadth, —, 7.3, 7.0; breadth of braincase, —, 7.2, 7.0; interorbital breadth, 3.5, 3.9, 3.8; length of maxillary toothrow, 5.0, 4.9, 4.8; breadth across upper canines, —, 3.3, 3.3; intermaxillary breadth at M3, 5.1, 5.2, 5.2; greatest length of mandible, 9.5, 9.4, 9.2.

Additionally, two female specimens of *M. yumanensis* from Nuevo León are deposited with the mammal collection of the Universidad Autónoma de Nuevo León. One specimen (UANL 1398) was collected on 22 October 1970 at Facultad de Agronomía, Cd. Universitaria, San Nicolás de los Garza; the other (UANL 794) was collected on 14 April 1973 at Rancho el Herradero, 14 km WSW of Hualahuises, Nuevo León. These localities are approximately 75 km NW, and 30 km SE respectively from Montemorelos. All localities are on the eastern side of the Sierra Madre Oriental and are lower than 700 m above sea level.

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DISTRIBUTIONAL RECORDS OF THREE MAMMALS FROM THE ROLLING PLAINS OF CENTRAL TEXAS

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All specimens documented in this report are deposited with the holdings of the Abilene Christian University Natural History Collection (ACUNHC).

On 15 March 1972, a specimen (ACUNHC 87) of the short-tailed grasshopper mouse (*Onychomys leucogaster*) was collected 3 miles SSE of Merkel in Taylor County, Texas. This species is primarily found in arid climates and lives in grassland or brushland environments. Soil in this habitat is usually sandy or fine-grained (Winkler 1990). These descriptions are consistent with the habitat of the Merkel area of Taylor County. This area is dominated by mesquite (*Prosopia glandulosa*), prickly pear cactus (*Opuntia engelmannia*) and small shrubs. The prevalent soil types are Tillman clay loam and Sagerton clay loam. Grasses found in this type of soil consist of short and mid grasses. They include side-oats grama (*Bouteloua curtipendula*), buffalograss (*Buchloe dactyloides*), Arizona cottontop (*Trichachne californica*), tobosa (*Hilaria mutica*), silver bluestem (*Andropogon saccharoides*) and two species of three-awn (*Aristida purpurea* and *Aristida wrightii*).

Onychomys leucogaster has never been recorded from Taylor County (Hall 1981; Jones & Jones 1992; Davis & Schmidly 1994). There are no specimens recorded from adjacent counties to the south of Taylor County (Coke, Coleman, Nolan or Runnels counties), although they are presumably within the range of this species (Davis & Schmidly 1994). However, adjacent counties to the north and east of Taylor County (Fisher, Jones and Callahan) do have records of this species. A recent extensive study of the fauna of Coke County by Simpson & Maxwell (1989) did not list *O. leucogaster* among the species reported.

Paleontological data suggests that the distribution of *O. leucogaster* once extended further east of its present distribution into central Texas. The most recent archeological data from central Texas (Longhorn Cavern, Burnet County) dates within the last 200 years (Winkler 1990). It is unclear whether this specimen is from a relic population or if it is from a population previously missed by collecting efforts.

On 10 October 1977, a specimen (ACUNHC 90) of the desert shrew (*Notiosorex crawfordi*) was collected on the Beckham Ranch in Callahan County. Although primarily found in desert areas, little is known about the nature of the habitat of *N. crawfordi*. Specimens have been found in cattail marshes, wood rat nests and bee hives (Davis & Schmidly 1994). The Callahan County specimen was trapped outside the recorded range of *N. crawfordi* as listed by Hall (1981), Jones & Jones (1992) and Davis & Schmidly (1994). This specimen is the first recorded for this county and extends its known range in central Texas. The nearest previously recorded specimens by Davis & Schmidly (1994) are from Baylor County (10 mi E and 85 mi N) and Coke County (30 mi S and 70 mi W).

An analysis of the data suggests that the range of *N. crawfordi* may be somewhat greater than is currently reported, but because so few specimens have been collected, little is known about their actual range and habitat. For this reason it is not known whether *N. crawfordi* is extending its range eastward or whether this specimen is from a population previously missed by collecting efforts.

On 26 April 1969, a specimen (ACUNHC 123) of an American beaver (*Castor canadensis*) was collected in Taylor County near Lawn, Texas. This specimen was trapped outside the recorded range of *C. canadensis*. This specimen is the first recorded for Taylor County and extends its known range in central Texas. The nearest previously recorded specimen (Simpson & Maxwell 1989) of *C. canadensis* is from Coke County (20 mi S and 50 mi W). There are no specimens recorded from surrounding counties (Runnels, Coleman, Tom Green and Concho), although they are presumably within range (Davis & Schmidly 1994). Both the Coke County specimen and the Taylor County specimen may indicate an isolated population of *C. canadensis* in the Rolling Plains of Central Texas.

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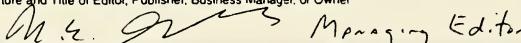
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