ASPECTS OF THE NATURAL HISTORY OF FRESHWATER TURTLES WITHIN THE LOWER RIO GRANDE VALLEY OF TEXAS

A Thesis

by

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Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 1977

Major Subject: Wildlife and Fisheries Sciences

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Approved as to style and content by:

(Chairman of Committee)

(Head of Department)

(Member)

(Member)

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ABSTRACT

Aspects of the Natural History of Freshwater Turtles
Within the Lower Rio Grande Valley of Texas
(August 1977)
Eric Kevin Grosmaire
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Chairman of Advisory Committee: Dr. James R. Dixon

Four species of freshwater turtles are reported from the lower Rio Grande Valley: Chrysemys concinna, Chrysemys scripta, Trionyx spiniferus, and Kinosternon flavescens. The distributional status and several aspects of the natural history of these species were investigated during the period of June-November, 1976.

Chrysemys concinna has been reported as occurring in the study area based on specimens from Cameron and Hidalgo Counties. It was concluded that these records were either misidentified or were individuals which had been introduced into the area. The remaining species were found occurring in all three counties included in the study area. The following aspects of the natural history of these species were investigated: relative abundance, population structure and sex ratio, population density, morphological variation, growth, food habits, and basking behavior.

It was found that C. scripta was the most abundant species followed by T. spiniferus and K. flavescens. Population structure, sex ratios, and population densities were calculated and found to be similar, in some cases, to those reported from other populations. Analysis of growth was based on differences in measurements of recaptured individuals, measurement of growth rings, and morphometric relationships. Growth was found to be variable. Food habit studies indicated that all three species eat similar food items, although they differed in the proportion of each item consumed. An attempt was made to study the basking behavior of C. scripta but not finalized. Field observations indicate that C. scripta in the study area are not as wary as has been reported for other populations.

The following topics were also discussed: 1) effects of sampling on the estimation of population characteristics, 2) comparative population structure and density, 3) comparative food habits, 4) basking behavior, and 5) the effects of man on turtle populations in the lower Rio Grande Valley.

ACKNOWLEDGEMENTS

Numerous individuals have contributed to the successful completion of this thesis. I would like to thank my advisor, Dr. James R. Dixon, for his advice, encouragement, and suggestions during the course of this research. I would also like to thank the other members of my committee, Drs. R. Douglas Slack and Fred E. Smeins, for their suggestions and loan of equipment.

This study would not have been possible without access to study sites and for this I graciously acknowledge numerous private individuals in the lower Rio Grande Valley for allowing me to come onto their property and the following members of the Department of the Interior's Fish and Wildlife Service for answering my innumerable questions and for their help during my stays at Laguna Atascosa and Santa Ana National Wildlife Refuges: Larry Dittos, Wayne Shifflett, and George Unland. Thanks are also due to Rey Ortiz and David Riskin of the Texas Parks and Wildlife Department for allowing me to work at Bentsen-Rio Grande State Park.

For information about turtles in the lower Rio Grande Valley, I acknowledge the help of Bryce C. Brown, Patrick M. Burchfield, Roger Conant, Frank W. Judd, Forrest Mitchell, and Robert H. Mount. For information about William A. "Snake" King, I thank Theodore Beimler, William A. King, Jr., and Hugh Skipwith. I thank George Zug of the U.S. National Museum for the loan of specimens in his care and David C. Whitman of the Cornell University Museum for attempting to find specimens deposited at that institution.

For their encouragement, free exchange of ideas, and friendship during this period, I thank my fellow graduate students: Drs. Robert A. Thomas and C. Mike Mather, Carlos Rivero-Blanco, Jack W. Sites, Okla W. Thornton, John A. Wiest, and Fred H. Wills. I thank Steve Hill, Robert Murray, Okla Thornton, and John Wiest for their assistance in identifying some of the food items encountered during the stomach content analyses.

Finally, I am especially grateful to C. P. "Tara" Kelley for her moral and financial support and patient understanding, without which this study would not have been possible. I would also like to thank Tara for preparing the drawings used in this thesis.

Financial support was provided by the Texas Agricultural Experiment Station, Project 1678.

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INTRODUCTION

There are four species of freshwater turtles recorded from the lower Rio Grande Valley of Texas, these are: 1) Chrysemys concinna texana, 2) Chrysemys scripta elegans, 3) Trionyx spiniferus emoryi, and Kinosternon flavescens flavescens. These species are widely distributed throughout eastern and/or central North America. While various aspects of the ecology of these species have been studied in other parts of their range, ecological investigations have not been conducted on those populations found in southern Texas. Furthermore, there has been a dramatic increase in numbers of people and cultivated land in the lower Rio Grande Valley during the last five decades which has had an impact on turtle populations in this area.

The objectives of this study were as follows: 1) to clarify the report of a disjunct population of C. concinna in the lower Rio Grande Valley, 2) to study different aspects (relative abundance, population structure and sex ratio, population density, morphological variation, movements, growth, food habits, basking behavior) of the natural history of species of turtles in the lower Rio Grande Valley in order to facilitate comparative intraspecific studies, and 3) to add to our knowledge of man's impact on turtle populations in anthropic situations.

McDowell's (1964) classification has been followed in using the name Chrysemys rather than Pseudemys for C. concinna and C. scripta.

The literature citations in this thesis follow the style of Herpetologica.

I followed this classification because comparative studies indicated close similarities in cranial morphology (McDowell, 1964), osteology (Weaver and Rose, 1967), and penial morphology (Zug, 1966) of these two groups. In addition, members of these groups have similar life histories. Inger (1958) and Mayr (1969) indicated that the total ecology of species should also be considered, in addition to comparative characters, when differentiating genera.

Objections have been raised to the congeneric relationship of Chrysemys and Pseudemys. Moll and Legler (1971) indicated that differences in coloration, markings and soft anatomy separate these genera. However, they note but do not consider variation in coloration and markings exhibited by members of the C. scripta complex and they do not present evidence that soft anatomy is an important taxonomic character in this group of emydid turtles.

LITERATURE REVIEW

Most of the natural history studies on the species of turtles investigated during this study were made on populations outside the state of Texas. Chrysemys concinna was reported from the lower Rio Grande Valley on the basis of specimens reported by Yarrow (1882) and Brown (1950). However, this species has not been seen in the area (Frank Judd, personal communication) and the presence of naturally occurring populations in this area has been questioned (Roger Conant, in litteris, 14 October 1976). Growth and population densities of C. concinna in Florida have been reported by Marchand (1942). Strecker (1927) reported that C. c. texana fed almost exclusively on mollusks (Sphaerium, Planorbis, Lymnae). Jackson (1970) studied growth in a Florida population.

Cagle (1942, 1944, 1946, 1950) has documented almost all aspects of the life history of Chrysemys scripta populations located in Illinois, Tennessee, and Louisiana. Several investigators (Cahn, 1937; Marchand, 1942; Minyard, 1947; Penn, 1950) have reported on the omnivorous food habits of this species. Auth (1975) made a detailed study of the basking behavior of this species in Florida, and Boyer (1965) studied basking in this and other species of turtles.

Population and habitat preference information on Trionyx spiniferus has been reported for populations in Illinois and Louisiana (Cagle, 1950; Cagle and Chaney, 1950). Growth was studied on individuals of this species in Minnesota (Breckenridge, 1955). A number of investigators (Cahn, 1937; Parker, 1939; Breckenridge, 1944; Penn, 1950; Anderson, 1965) have reported the carnivorous food habits of this species. Webb (1962) has summarized much of the life history data on this species.

Surprisingly little information has been compiled on the life history of Kinosternon flavescens. Strecker (1927) reported on food preferences of captives from Texas. Mahmoud (1960, 1967, 1968, 1969) studied the ecology of this species in Oklahoma.

THE STUDY AREA

This study was conducted during the months of June-November, 1976, in the lower Rio Grande Valley (Rio Grande floodplain) of Texas. The study area included all of Cameron and Willacy Counties and the eastern portion of Hidalgo County. The boundaries of the study area are: south of a line along state highway 186 from Port Mansfield to Raymondville, then west from state highway 77 along FM 490 to state highway 281; 281 north of Edinburg and FM 2221 form the western boundary; the Rio Grande River and the Gulf of Mexico form the southern and eastern boundaries (Figure 1).

The area delimited includes all of the Pleistocene-Recent delta of the Rio Grande River (Trowbridge, 1932) except the most northerly portion found in southern Kenedy County. This area lies entirely within Blair's (1950) Tamaulipan Biotic Province or Gould's (1969) South Texas Plains area. Blair (1950) lists the following plants as being characteristic of the area: mesquite (*Prosopis juliflora*), granjeno (*Celtis pallida*), lignum vitae (*Porliera augustiflora*), cenizo (*Leucophyllum texanum*), white bush (*Aloysia texana*), prickly pear (*Opuntia lindheimeri*), tasajillo (*Opuntia leptocaulis*), *Acacia* sp., *Mimosa* sp., *Condalia* sp., and *Castela* sp. The vegetation in the area between Brownsville and the mouth of the Rio Grande (Blair's Matamoran District) is more luxuriant and includes: retama (*Parkinsonia aculeta*), Texas ebony (*Siderocarpus flexicaulis*), wild olive (*Cordia boissieri*), knackway (*Chretia elliptica*), elm (*Ulmus crassiflora*), and sabal palm (*Sabal mexicana*).

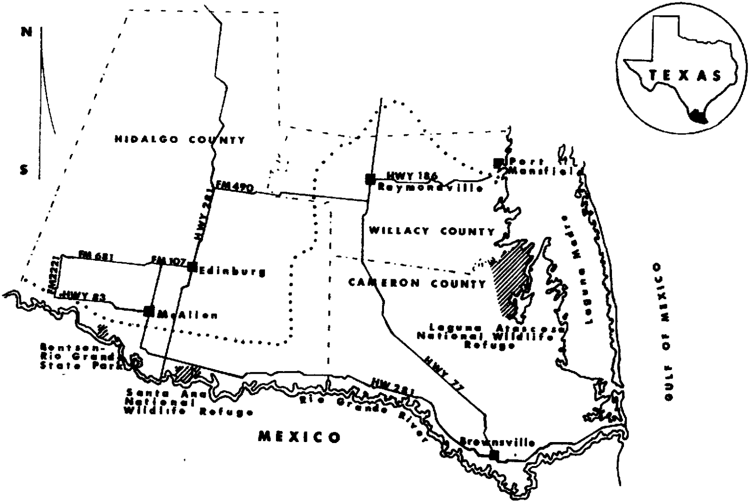


Figure 1. Map of the study area and Trowbridge's (1932) boundary of the Pleistocene-Recent delta (dots) of the Rio Grande River.

For a number of years, the study area has been subjected to extensive agricultural practices and as a result, much of the natural vegetation has been destroyed. Large tracts of naturally occurring vegetation are still found in eastern Willacy County as a result of ranching and on the Santa Ana and Laguna Atascosa National Wildlife Refuges. In these areas, mesquite is one of the dominant trees. Johnston (1963) indicated that mesquite has been present in the study area for a long period of time, although many years ago it had a stunted growth form due to frequent fires. With the advent of fire control, mesquite increased both the stature of its aerial portions and the stand density. As a result the nature of the area changed from mesquite-prairie to mesquite-brush (Johnston, 1963).

The climate of the area has been classified by Thornthwaite (1948) as megathermal. It is a zone of semi-aridity with relative high temperatures and a fairly constant east wind. The aridity results from the area being located immediately south of a belt of permanent high atmospheric pressure (Trowbridge, 1932).

Lowest monthly temperatures are recorded during January, with the highest temperatures occurring during July-August (Figure 2). The average monthly temperature for the period (June-November, 1976) in which this study was conducted was 24.8^{o}C, while the average monthly temperature for these same months during the period of 1882-1974 was 27.6^{o}C (National Oceanic and Atmospheric Administration, Environmental Data Service). Rainfall occurs mainly during the spring (May-June) and early autumn (September-October) (Figure 3). The average precipitation for the period in which this study was conducted was

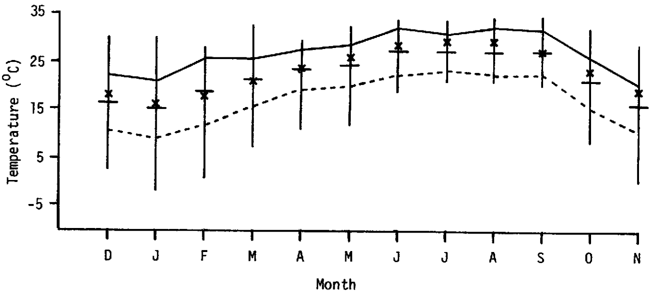


Figure 2. Monthly variation in temperature for Brownsville, Texas, for the period within which this study was conducted (December, 1975-November, 1976): horizontal bar, mean; vertical bar, range; solid line, average high temperature; and broken line, average low temperature. For the period, 1882-1974, x's indicate the average monthly temperature (National Oceanic and Atmospheric Administration, Environmental Data Service).

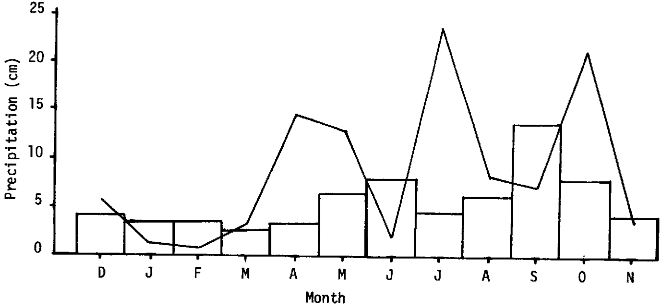


Figure 3. Average monthly precipitation (1870-1974) for Brownsville, Texas (vertical bars), and the monthly precipitation (line) during the period (December, 1975-November, 1976) within which this study was conducted (National Oceanic and Atmospheric Administration, Environmental Data Service).

12.6 cm, while the average monthly precipitation for these same months during the period of 1870-1974 was 8.3 cm (National Oceanic and Atmospheric Administration, Environmental Data Service).

Aquatic habitats in the lower Rio Grande Valley consist of the Rio Grande River, resacas or oxbows (former channels of the Rio Grande), the Arroyo Colorado, and manmade projects (reservoirs, cattle tanks, irrigation canals). The major resacas in the area are the Resaca de los Fresnos, the Resaca de las Cuates, and the Resaca del Rancho Viejo. The number of resacas increases from north to south and from west to east, while the number of manmade projects increases inversely.

The following is a description of the sites at which population studies were conducted: a) Willow Lake and Cattail Lake-these sites are located in the Santa Ana National Wildlife Refuge and both are former channels of the Rio Grande River. Both sites have been divided into three impoundments by low dikes. They are approximately the same size, each having a surface area of about 6.8 ha. Water depth exceeds 1.5 m in some areas. Aquatic vegetation is present to varying degrees in the different impoundments. Terrestrial vegetation extends almost to the water's edge. Cattail Lake is approximately 1.6 km SW of Willow Lake. During the month of August, 1976, the refuge was flooded as a result of the water letdown from Falcon Reservoir. This increased the water depth in Willow Lake approximately 2 1/2 times and the overflow from this site filled two previously dry, vegetatively overgrown impoundments at Cattail Lake. b) Headquarters Pond-this site is located in the headquarters compound at Laguna

Atascosa National Wildlife Refuge. It has a surface area of approximately 0.45 ha and a depth of 1.4-1.7 m. There is some aquatic vegetation present and the terrestrial vegetation extends to the water's edge. c) Resaca-this site is located on the western boundary of Bentsen-Rio Grande State Park. The surface area is unknown, although it is larger than either Willow or Cattail Lakes (above). The water depth exceeds 1.7 m a short distance from the shoreline. Natural vegetation is found along the eastern shore. The other three sides are being farmed.

MATERIALS AND METHODS

Turtles were trapped using 76.2 cm diameter, double-throated hoop nets. Bait consisted of canned fish, fresh fish, or beef scraps. Once caught, turtles were sexed, and the following measurements taken: 1) carapace length (CL)-minimum distance along the dorsal midline, 2) carapace width (CW)-maximum width of the carapace, 3) plastron length (PL)-maximum length of the plastron, 4) plastron hind lobe width (PHLW)-maximum width of the femoral scutes, 5) shell depth (SD)-maximum height of the shell, 6) abdominal scute length (AL)-length of the right abdominal scute along the plastral midline. Only the first three measurements were taken on *Trionyx spiniferus* and the shell depth was taken at the level of the bridge in *Kinosternon flavescens*. In the field, distances were measured with homemade vernier calipers which were then laid on a steel rule. In this case, measurements were to the nearest 1.0 mm. In the lab, measurements were made with dial calipers to the nearest 0.5 mm. Size or length of turtles, unless otherwise noted, refers to the plastral length.

Turtles were sexed using secondary sexual characteristics. Adult (PL>90 mm) *C. scripta* males are characterized by having elongated foreclaws and a vent which lies outside the posterior edge of the carapace when the tail is straightened. Individuals were judged to be females, if their plastron length exceeded 90 mm and they lacked these characteristics. *Kinosternon flavescens* males possess a large tail tipped with a horn and a rough patch of scales on the inside of the thighs. Individuals which lacked these characteristics were judged to be females. Male <u>Trionyx spiniferus</u> are characterized by having a tail that extends further beyond the posterior edge of the carapace than does the female's.

Systematic mark-recapture studies were carried out at three locations in the study area: Bentsen-Rio Grande State Park, Santa Ana National Wildlife Refuge (Santa Ana NWR), and Laguna Atascosa National Wildlife Refuge (Laguna Atascosa NWR). At these sites, each captured *C. scripta* and *K. flavescens* was marked with a unique combination of notched marginals, so that individuals could be recognized if captured at a later date (Figure 4). Captured *T. spiniferus* were marked with numbered metal fish tags attached to the posterior edge of the carapace.

While conducting mark-recapture studies, traps were monitored for 48 continuous hours at one location. During this period, traps were checked and rebaited twice daily, usually between 0900-1000 and 1600-1700hrs. During the trapping periods at Santa Ana National Wildlife Refuge, traps were operated in each impoundment of Cattail and Willow lakes in the manner described above.

Notes were taken on the configuration of the postorbital markings and the degree of melanism exhibited by individual *C. scripta*. The configuration of the postorbital markings was divided into the following categories: 1) a broad postorbital bar, 2) a postorbital bar which was narrowed anteriorally, 3) a postorbital bar which was constricted anteriorally, and 4) a postorbital bar which consisted of separated supratemporal and postorbital spots (Figure 5).

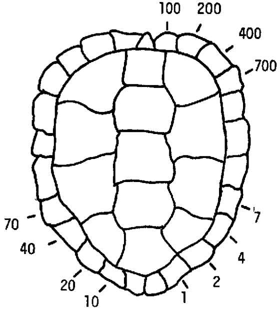
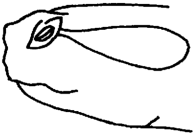
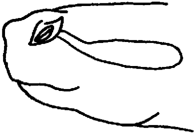


Figure 4. Numbering system used to mark Chrysemys scripta and Kinosternon flavescens from the lower Rio Grande Valley of Texas. Turtles were marked by notching various combinations of marginals to give the desired number. For example, "135" would have the following marginals notched: 100, 20, 10, 4, 1.



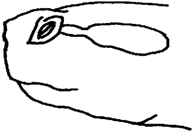
Broad Postorbital Bar

(Field Number 184)



Narrowed Anteriorally

(Texas Cooperative Wildlife Collection 52367)



Constricted Anteriorally

(Texas Cooperative Wildlife Collection 52349)

Separated Spots

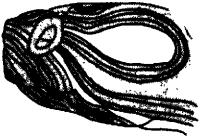
(Texas Cooperative Wildlife Collection 52366)

Figure 5. Different postorbital markings found on Chrysemys scripta from the lower Rio Grande Valley of Texas.

Melanism was determined on a different basis for male and female *C. scripta*. In males, the classification was restricted to the soft parts. This was done on the following basis: 1) non-melanistic-exhibiting a typical juvenile head pattern, 2) partially melanistic-partial or complete disruption of the juvenile head pattern, but with the postorbital configuration remaining unaltered, and 3) fully melanistic-complete disruption of the juvenile head pattern and partial or complete alteration of the postorbital configuration (Figure 6). In females, the classification was restricted to changes in the plastral pattern. This was done on the following basis: 1) non melanistic-a distinct, separate, dark smudge on each plastral scute, 2) partially melanistic-a coalescing of some of the dark smudges, but with some remaining distinct, and 3) fully melanistic-all of the plastral smudges were incorporated into the coalescense.

In addition to studying movements of *C. scripta* based on recaptures, this phenomena was also studied through the use of "flagged" individuals. A hole was drilled in the carapace in the vicinity of the nuchal scute, after which a 20 cm dowel with a piece of brightly colored ribbon attached at one end was inserted. This individual could then be observed through binoculars and its position noted.

Specimens obtained for food habit analyses were killed as quickly as possible after capture to halt the action of the digestive processess. Specimens were then preserved in 10% formalin and later transferred to 70% ethyl alcohol. All specimens examined were adults.



Non-Melanistic

(Texas Cooperative Wildlife Collection 52358)

Partially Melanistic

(Texas Cooperative Wildlife Collection 52362)

Fully Melanistic

(Texas Cooperative Wildlife Collection 52403)

Figure 6. Different stages of melanism in male Chrysemys scripta from the lower Rio Grande Valley of Texas.

Analyses of the stomach contents were conducted in the following manner: the stomach was removed by cutting the digestive tract at the pyloric sphinctor muscle and as far anteriorad along the esophagus as possible. The stomach was then opened and the contents removed and sorted under low magnification. Plant material was not sorted into different taxonomic groups, invertebrates were identified to Order; and, vertebrate material identified to Family, when possible. Volume of each kind of food item was determined by water displacement in either a graduated cylinder or graduated syringe. The presentation of data pertaining to the stomach contents was expressed as follows: 1) numerical percent-the number of individuals of a particular food item expressed as a percentage of all food items, 2) volumetric percent-percentage of the total volume of food items comprised by a given kind of food item, 3) frequency percent-percentage of stomachs in which a given food item was found. Pinkas et al. (1971) calculated an Index of Relative Importance (IRI) in order to determine the importance of the various food items in the overall diet of a species. The IRI is calculated as follows:

$$IRI=(N+V)F$$

N=numerical percent

V=volumetric percent

F=frequency percent

Basking studies were conducted at the Headquarters Pond (H.Q. Pond) in the Laguna Atascosa National Wildlife Refuge. After turtles were caught, the following data were taken: sex, plastron length, and volume. The last measurement was obtained by water displacement.

Each individual was assigned a number and this number was painted on the anterior and lateral portions of the carapace to facilitate recognition at a distance. Data recorded while turtles were on the basking site included: air temperature, light intensity, and time of mounting and dismounting for each individual. Temperature was measured with a Yellow Springs Telethermometer and the light intensity was measured with a Cossen Lunasix 3 light meter.

RESULTS AND DISCUSSION

Chrysemys concinna texana (Baur)
(Texas Slider Turtle)

Distribution and Status of Populations Reported in the Lower Rio Grande Valley

Conant (1975) reported that this form ranges from eastern Texas west to the Pecos River, follows the river north into southeastern New Mexico and south into the Mexican states of Coahuila and Nuevo Leon and has a disjunct population located in the lower Rio Grande Valley. This species was not caught or observed in the study area. Individuals are present in the Gladys Porter Zoo, Brownsville, Texas, which were supposedly caught in the Resaca de las Cuates at the junction of FM 1421 and state highway 100 in Cameron County (Patrick M. Burchfield, *personal communication*).

Location of populations of this species in the study area has been on the basis of two specimens reported from Cameron County (Yarrow, 1882) and one from Hidalgo County (Brown, 1950). One of the Cameron County specimens (United States National Museum 8927) was examined and identified as being a *C. scripta* (James R. Dixon, *personal communication*), the other has also been reported as being a *C. scripta* (Roger Conant, *in litteris*, 14 October 1976). The Hidalgo County specimen (Cornell University 2146) has been lost (David C. Whitman, *in litteris*, 30 November 1976).

The specimen reported from Hidalgo County was collected near Edinburg in 1933 (Bryce Brown, *in litteris*, 30 November 1976). Frank Judd (*personal communication*) is familiar with this area and has never observed individuals of this species. Conant (1977) is of the opinion that any *C. concinna* reported from the lower Rio Grande Valley were more than likely introduced into the area as a result of the activities of William A. "Snake" King, a commercial animal collector. Mr. King operated an enterprise known as "Snakeville" in Brownsville, Texas, during the period of 1907-ca. 1954. Ted Beimler (*personal communication*), a longtime resident of Brownsville, and Hugh Skipwith (*personal communication*),a former employee at Snakeville, have indicated that when the population of captive animals became too large or individuals became diseased, they were released into the surrounding area. Thus the specimen of *C. concinna* captured near Edinburg may have been there as a result of these or similar activities.

The following hypothesis is offered for the presence of *C. concinna* in Texas and north-central Mexico: Crenshaw (1955) suggested that this species may have evolved during the Wisconsin period. Preston (1966) believes that this species may have been a late arrival in Texas due to its absence from the fossil record. Pedological evidence (Bryan and Albritton, 1943), fossil evidence (Milstead, 1967; Holman, 1969), and the presence of populations of amphibians and reptiles, which are considered to be mesically adapted, in the Chihuahuan Desert (Milstead, 1960) suggest that southern and western Texas and northern Mexico had, at one time, a cooler and/or moister climate. Dorf (1959) concluded that Pleistocene interglacials in Texas had a subtropical climate. Knapp (1953) indicated that during the Pleistocene, tributaries of rivers were much more extensive and stream piracy more common, thereby allowing species to move from one drainage system to another. These may have been the circumstances which allowed _C. concinna_ to expand its range southwards through Texas into northern Mexico.

The following hypothesis is offered for the absence of _C. concinna_ in the lower Rio Grande Valley during Recent times: Cahn (1937) and Crenshaw (1955) indicated that _C. concinna_ is a stream dwelling form and not adapted for moving overland. Milstead et al. (1950) and Raun (1959) found that while both _C. concinna_ and _C. scripta_ were present in streams, several hundred meters away in stock ponds, only _C. scripta_ was present. Mount (1975) indicated that this species seldom comes onto land except to nest.

Raun and Gelbach (1972) indicated that _C. concinna_ is present in parts of the Nueces River drainage, although Robert H. Mount (_in litteris_, 29 March 1977) has yet to find any in the Nueces-Frio system. The Nueces River is the first major drainage system north of the lower Rio Grande Valley, with a distance of approximately 242 km separating them. Hubbs (1957) indicated that a faunal break exists between these two areas. Thus, the fact that _C. concinna_ has little tendency to move overland, coupled with the wide interval separating the Rio Grande from the Nueces River would seem to prohibit the dispersal of this species into the lower Rio Grande Valley from areas to the north.

While C. concinna has been caught in the Rio Grande River at Falcon and Amistad Reservoirs, its population densities are low (Robert H. Mount, in litteris, 29 March 1977). Degenhardt and Christiansen (1974) did not report this species as being present in the Rio Grande River in New Mexico, although they did report all three species of aquatic turtles found in the study area at the present time. Baird (1859) did not report C. concinna as being present in his survey of reptiles along the U.S.-Mexican boundary, although he also listed the three species of aquatic turtles which are found in the lower Rio Grande Valley at the present time.

Raun and Gelbach (1972) listed as localities for C. concinna the Devils and Pecos Rivers, both of which drain into Amistad Reservoir. Legler (1960a) listed as localities in northern Mexico, sites which are on the Rio Sabinas-Rio Salado drainage which empties into the Rio Grande River just north of Falcon Reservoir. These facts in conjunction with the absence of C. concinna from the Rio Grande River as reported by Baird (1859) and Degenhardt and Christiansen (1974) suggest two explanations: 1) Chrysemys concinna is present in the Rio Grande River, but due to its low abundance is seldom reported, or 2) that this species does not normally occur in the Rio Grande River, but that the impoundment of the river in areas with tributaries which contain C. concinna has created favorable habitats which in turn has allowed this species to move into the river.

This species will not be discussed further in this thesis.

Chrysemys scripta elegans (Wied)
(Red-eared Turtle)

Distribution and Status of Populations Reported in the Lower Rio Grande Valley

Chrysemys s. elegans is found from Indiana south through Alabama, western Georgia, and the Florida Panhandle to the Gulf of Mexico; west through Missouri, Kansas, Oklahoma, and Texas into eastern New Mexico and northeastern Mexico (Conant, 1975). This form was caught in all three counties included within the study area and represents a new county record for Willacy County (see Appendix A for localities).

Relative Abundance

Although C. scripta is found in many types of aquatic situations throughout its range, it is most often found in quiet backwater areas with abundant vegetation and suitable basking sites (Cagle, 1950). The study area's warm equable climate and numerous resacas would seem to provide ideal conditions for the support of large populations of this species. Of the three species of aquatic turtles found in the study area, this species was the most abundant, making up 84.0% of all turtles (N=770) captured. The relative abundance of this species at different sites in the study area is presented in Table 1. In other parts of its range, C.s. elegans has been found to comprise 20-87% of the populations in Illinois (Cagle, 1942), 33.4-96.2% in Louisiana (Cagle, 1950; Cagle and Chaney, 1950), 2.4% in Gulf Coast rivers (Tinkle, 1958a: Table 28), 75% in Kentucky (Ernst and Barbour,

Table 1. Relative abundance of three species of aquatic turtles at different sites in the lower Rio Grande Valley of Texas.

Locality	N	*C.s. elegans*	*T.s. emoryi*	*K.f. flavescens*
Bentsen-Rio Grande State Park	21	72.7%	27.3%	____
Santa Ana NWR Willow Lake (pre-flood)	184	100.0%	____	____
(post flood)	22	51.7%	48.3%	____
Cattail Lake	45	97.6%	____	2.4%
Laguna Atascosa NWR Overall	25	75.0%	12.5%	12.5%
H.Q. Pond	11	90.9%	____	9.1%
Resaca de los Fresnos	5	____	100.0%	____

1972), and 64% in Lake Texoma, Oklahoma (Webb, 1961). The wide range of frequencies is because this species is more numerous in larger bodies of water (Cagle, 1942).

Population Structure and Sex Ratio

A total of 438 C. scripta were examined during the course of this study, of which 92.9% were adults. Only three individuals were caught that were smaller than 90 mm in length. Cagle (1942) 1950) found that adults comprised 81% and 69% of populations in Illinois and Louisiana, respectively. Webb (1961) found that 55% of the C. scripta population in Lake Texoma, Oklahoma, were adults, while Moll and Legler (1971) reported that adults comprised 63% of Panamanain populations. A breakdown of each of these populations is presented in Table 2. This table indicates that the percentage of males does not vary to a considerable degree between populations, while that of females and juveniles does fluctuate. This fluctuation may be the result of several factors, including variation in size at which females mature (Webb, 1961; Moll and Legler, 1971), increased exposure to terrestrial predators during nesting (Gibbons, 1968) or dispersal during the juvenile stages (Cagle, 1950).

Figure 7 indicates the size class frequency of C. scripta caught in the study area. This species is sexually dimorphic with respect to the maximal sizes attained by both sexes (Cagle, 1950). The largest male caught during this study had a plastron length of 191 mm while the largest female was 251 mm long. The average plastron length (and 95% confidence interval) of adult males (PL>90 mm) was 145.2 ± 3.0 mm, the

Table 2. Age and sex class composition of populations of *Chrysemys scripta* reported in the literature. Localities are arranged from north to south.

Locality	N	Adult Male	Adult Female	Juvenile	Source
Southern Illinois	1376	34.2%	46.7%	19.1%	Cagle, 1942
Lake Texoma, Oklahoma	98	42.0%	13.0%	43.0%	Webb, 1961
Louisiana	1202	33.3%	35.3%	31.4%	Cagle, 1950
Southern Texas	440	45.2%	47.5%	7.1%	This study
Panama	330	41.6%	21.6%	36.8%	Moll and Legler, 1971

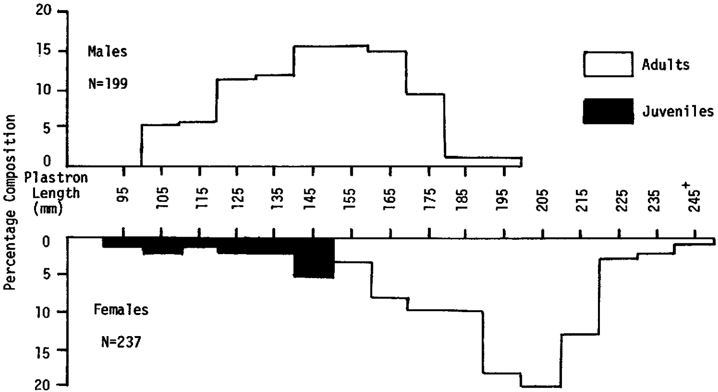


Figure 7. Frequency distribution of the size classes of *Chrysemys scripta* trapped in the lower Rio Grande Valley of Texas. The size class "95" includes all plastron lengths from 90-99, "105" includes those from 100-109, etc.

average length (and 95% confidence interval) of adult females (PL> 150 mm) was 193.9 ± 2.63 mm, and the average length (and 95% confidence interval) of juvenile females (90<PL<150 mm) was 130.6 ± 5.87 mm.

The sex ratio (male:female) was 199:237. Cagle (1950) found the sex ratio of populations in Louisiana to be 419:783. There is evidence that the method of capture may bias the estimates of different population characteristics of a species (see Conclusion section).

Population Density

Of the 262 *C. scripta* marked at four population study sites, only 6.9% were recaptured. Four different methods of estimating population sizes were used in this study: The Maximum Likelihod Equation ($\hat{N}$=no. marked/1-[no. marked/no. captures]).and the frequency of Capture Regression (Edwards and Eberhardt, 1967) and the Schnabel Method and Lincoln Index (Smith, 1974). In order to obtain an estimate of the population size of those species in which there were no recaptures, e.g. *Kinosternon flavescens*, the size of the entire turtle population, regardless of species, was calculated. Then, the size of the population for each species was estimated by multiplying the entire population estimate by the percentage of captures figure. Table 3 indicates a wide variation in the estimate of the population size at each locality, with the highest estimate ranging from 2.0-3.7 times the lowest estimate. Because methods of estimating population sizes are based on recaptures, this variation is to be expected in a study where the number of recaptures is minimal. There is evidence

Table 3. Population estimates and calculated density of three species of freshwater turtles at different sites in the lower Rio Grande Valley of Texas.

Locality/Species	No. Marked/ No. Recaptured	Population Estimate/Calculated Density (nos./ha)			
		Maximum Likelihood Equation	Frequency of Capture Regression	Schnabel Method	Lincoln Index
Santa Ana NWR					
Willow Lake (pre-flood)					
C. scripta	184/7	4973/730	4282/630	1342/200	1587/230
(post-flood)					
C. scripta	15/0	132/20	112/20	46/7	43/6
T. spiniferus	14/2	143/20	121/20	50/7	47/7
Cattail Lake					
C. scripta	44/4	538/80	398/60	356/50	274/40
T. spiniferus	1/0	11/2	8/1	7/1	6/1
Laguna Atascosa NWR					
H.Q. Pond					

Table 3 (continued)

Locality/Species	No. Marked/ No. Recaptured	Population Estimate/Calculated Density (nos./ha) Maximum Likelihood Equation	Frequency of Capture Regression	Schnabel Method	Lincoln Index
C. scripta	10/5	33/70	11/20	25/60	38/90
K. flavescens	1/0	2/4	1/2	2/4	2/4

that turtles which have been handled are warier than those which have not been handled. This problem is discussed further in the Conclusions section.

Table 3 lists the density of each species at each population study site. The densities, as reported in the literature, for C. scripta and other pond dwelling emydid turtles are listed in Table 4. The Lincoln Index estimate from the H.Q. pond (Laguna Atascosa National Wildlife Refuge) was used in Table 4, as it was the site at which the percentage of recaptures was greatest and presumably the estimate of the population density the most accurate. In addition, most of the sources in Table 4 also used the Lincoln Index to estimate density. Less precise data on population densities of C. scripta were given by Cagle (1950) who reported that it was not unusual to observe 50-100 heads/100 sq. ft. of water surface in favorable areas and Tinkle (1958b) who reported 1 C. scripta/17 yds of river. Cagle (1950) noted several factors which permitted dense populations to occur in favorable areas, including: lack of intraspecific aggression, omnivorous food habits, and the ability to go without food for a long period of time.

Melanism

For many years, the marked sexual dichromatism found in larger individuals of C.s. elegans caused taxonomic confusion until Viosca (1933) explained that the form C.s. troostii was merely a melanis-

Table 4. Densities of some aquatic emydid turtles as reported in the literature.

SPECIES	LOCALITY	DENSITY (nos./hectare)	SOURCE
Chrysemys scripta	Illinois	27	Cagle, 1942
	S. Carolina	88	Gibbons, 1970a
	Texas	89	This Study
	Panama	164-185	Moll and Legler, 1971
Chrysemys picta	Michigan	576	Gibbons, 1968
	Michigan	99-410	Sexton, 1959
	Wisconsin	43	Ream and Ream, 1966
	Pennsylvania	590	Ernst, 1971
Clemmys muhlenbergii	New Jersey	124	Eglis, 1967
Clemmys marmorata	California	430	Bury, 1975

Table 4 (continued)

SPECIES	LOCALITY	DENSITY (nos./hectare)	SOURCE
Deirochelys reticularia	S. Carolina	40	Gibbons, 1970a
Terrapene coahuila	Mexico	148	Brown, 1974

tically pigmented C.s. elegans. An account of the progressive changes in the soft parts is given by Barbour and Carr (1940) and in the plastron by McCoy (1966).

Several investigators (Cahn, 1937; Cagle, 1950; Webb, 1961) have pointed out that the size at which fully melanistic individuals appear is geographically variable. The earlier investigators (Cahn and Cagle) believed that this size became smaller as one progressed southwards through the range of C.s. elegans. Melanism does not occur to the same degree in Neotropical members of the C. scripta complex as it is in North American and West Indian forms (Carr, 1952; Moll and Legler, 1971). McCoy (1966) reviewed the literature on this subject and found that while the size at which fully melanistic individuals appear is variable, there were no apparent north-south trends.

In the following discussion, melanism in males refers to changes in pigmentation of the soft parts. This facet of melanism in males was chosen for quantification because it is this change which is the most striking. Melanism in females is restricted to changes in plastral pigmentation. The different degrees of melanism in males is presented in Figure 6.

In this study, I found that almost all males smaller than 140 mm were non-melanistic, with partial and full melanism appearing in individuals larger than 140 mm and thereafter increasing in frequency until all individuals larger than 170 mm were fully melanistic (Figure 8). The smallest male exhibiting full melanism was 136.5 mm in length.

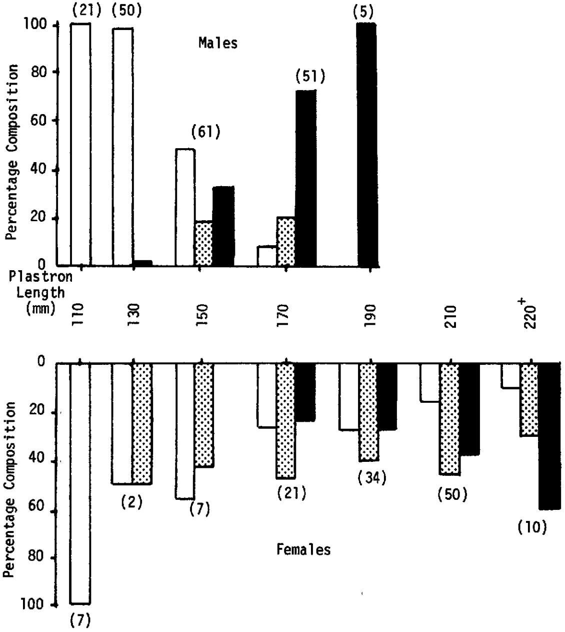


Figure 8. Frequency of melanism in different size classes of <u>Chrysemys scripta</u> from the lower Rio Grande Valley of Texas; non-melanistic-white bars, partially melanistic-stippled bars, fully melanistic-black bars. Numbers in parentheses indicate sample size. Explanation of size classes as in Figure 7.

In females, non-melanism was found in all size classes with partial and full melanism appearing at 120 mm and 160 mm, respectively (Figure 8). The smallest fully melanistic female was 162 mm in length. Only one female (PL=236 mm) exhibited any modification of the typical head pattern and it was similar to that found in the early stages of partially melanistic males.

Cahn (1937) and Barbour and Carr (1940) believed that not all males in a population became fully melanistic, although results to the contrary were found by Webb (1961), McCoy (1966), and this study. In this study, it was found that melanistic males made up 44.7% of all males (N=188) examined.

Contrary to McCoy's (1966) findings, not all females were observed to undergo extensive melanistic changes in the plastral pattern, although those that did followed the same pattern of change as described by him. Webb (1961) found that some females from Lake Texoma, Oklahoma, had plastrons that were 80% melanistic. Several females were found during the course of this study that were 95% melanistic, i.e. only the very edges of the plastron retained any yellow pigmentation.

The incongruity of Cagle's (1950) findings for central Texas (Table 5) may be the result of his use of a black smudge on the plastral scutes as a sign of melanism. Juvenile C.s. elegans have an ocellus on each plastral scute which is obscured by the deposition of melanistic pigment as they reach sexual maturity (Carr, 1950). As pointed out by McCoy (1966), the fact that there are no apparent

Table 5. Minimum size at which fully melanistic males from populations of *Chrysemys scripta elegans* have been reported in the literature. Localities are arranged from north to south.

Locality	Size (mm)	Source
Illinois	152	Cahn, 1937
	126	Cagle, 1948
	130	Cagle, 1950
Tennessee	130	Cagle, 1950
Lake Carl Blackwell, Oklahoma	145	McCoy, 1966
Lake Texoma, Oklahoma	152	Webb, 1961
Central Texas	100	Cagle, 1950
South Texas	136.5	This study

north-south trends in the size at which melanism appears may be obscured by the criteria used to define the term "fully melanistic."

Postorbital Markings

The variation in the configuration of the postorbital markings found in C.s. elegans from the lower Rio Grande Valley was, at one time, attributed to integradation between C.s. elegans, C.s. gaigeae and forms in northern Mexico (Hartweg, 1939; Hamilton, 1947; Cagle, 1950; Carr, 1952). More recent investigations (Webb, 1961) have attributed this variation to individual differences.

Four types of postorbital markings were found in the study area. They were (in decreasing order of abundance): 1) separated supratemporal and postorbital spots, 2) postorbital bar narrowed anteriorally, 3) postorbital bar constricted anteriorally, and 4) a broad postorbital bar (Figure 5). The frequency of these configurations varied in different parts of the study area, but this may be attributable to inbreeding within local populations. An analysis was also made to determine if ontogenetic changes (e.g. narrowed anteriorally to constricted anteriorally to separated spots) were responsible for the variability observed. However, these configurations were found in all size classes.

Some individuals exhibited markings which were different on either side of the head. The most frequent postorbital markings involved in this category were those with separated spots on one side and a postorbital bar which was constricted anteriorally on the opposite side. In a few instances, the distance between the separated spots was quite different on either side of the head. Table 6 indicates the geographic variability of these configurations.

A possible explanation for the variability of these configurations may be found in the effect of alternating periods of mesic and xeric conditions on the distribution of this species during the Pleistocene. Fossil evidence indicates that this species was well established in the Pleistocene of Texas (Holman, 1969). During the sequence of glacial and interglacial periods, with their associated climatic and vegetational changes, the range of this species expanded eastwards along the Gulf Coast Corridor during favorable periods and contracted or fragmented during unfavorable periods (Auffenberg and Milstead, 1965). Preston (1966) suggested that turtles similar to C.s. elegans may have moved eastward into Florida during warm and/or dry periods and southwards into Mexico during cool and/or moist periods. The period of expansion would have allowed populations to become established in the discontinuous river systems of Oklahoma and Texas, where isolation and inbreeding could have occurred during the unfavorable periods, thus providing an opportunity for the various types of postorbital markings to become fixed in the population. Hobbs (1950) stated that during the glacial periods, the Mississippi River was greatly enlarged by tremendous volumes of summer meltwater, this in conjunction with the encroachment of the Mississippi Embayment during the interglacials may have isolated a population of this species east of the Mississippi. The period of isolation could have allowed a broad postorbital bar to become fixed in this population. Tinkle (1958a) and Webb (1962) have indicated that this sequence of events may have been responsible for

Table 6. Geographic variability in the frequency of the postorbital markings of Chrysemys scripta elegans as reported in the literature. Localities are arranged from north to south.

Locality	Broad Bar	Narrow/ Constricted	Separated Spots	Different	Source
Mississippi R. Valley	100%	____	____	____	Cagle, 1950
Lake Texoma, Oklahoma	49%	25%*	26%	____	Webb, 1961
Louisiana	90-95%	trace	5%	____	Cagle, 1950
Southern Texas	0.6%	37.2%**	51.4%	10.6%	This Study

* Includes those in "different" category

** Narrow=20.7%, Constricted=16.5%

differentiation of southeastern forms in the Sternotherus and Trionyx complexes. Following the last glacial period, these populations of C. scripta may have expanded their range northwards through the Mississippi Valley, accounting for the presence of a wide postorbital bar in 100% of the populations in this area (Table 6).

Movements

The most complete studies of movements in aquatic turtles have been made by Cagle (1944) on C. scripta and Sexton (1959) on C. picta. Moll and Legler (1971) have reported on the movements and home ranges of C. scripta in Panama. Cagle (1944) concluded that populations of C. scripta occupied a particular stream section or lake, with individuals occupying areas which may include all or parts of adjacent bodies of water and they remained in that area until stimulated to leave for one of the following reasons: breeding cycle, seeking hibernacula, drastic habitat changes.

Movements of C. scripta observed during this study fell into three categories: daily movements, short migrations, and movements resulting from habitat changes. Observations on daily movements were made on "flagged" individuals and by the recapture of marked individuals. In the Santa Ana National Wildlife Refuge, C. scripta moved between adjacent impoundments, although a preference for specific impoundments was noted. Six turtles marked in late June, 1976, in the western impoundment of Santa Ana's Willow Lake were recaptured about ten days later in the eastern impoundment. The east and west impoundments are separated by a third intermediate impoundment over 300 m in length. The middle impoundment was the only one of the three that did not contain an island, contained the least amount of aquatic vegetation, and had the fewest number of captures (7 of 190). Prior to the flooding of two additional impoundments at Cattail Lake, the one containing water had very little aquatic vegetation present. A total of 31 C. scripta were marked and released in this impoundment. After the flooding, only one turtle was captured in this impoundment, while 45 other captures were made in the other two impoundments, both of which contained extensive amounts of vegetation. Sexton (1959) found that established individuals in certain areas sometimes journeyed outside these areas. He thought that these "extralimital" journeys might be in response to a deficiency of some essential resource, usually food, and that this deficiency stimulated the movement. He noted that 20% of his captures exhibited extralimital movements.

Studies of nocturnal activity were undertaken by marking the position of flagged individuals close to sunset and then rechecking this position at various times throughout the night. Two individuals were observed for three nights each. These individuals spent the night near the surface or resting quietly on the bottom, as reported by Cagle (1944). Moll and Legler (1971) reported that Panamanian populations of C. scripta exhibited little nocturnal movement. Of the two individuals followed, one returned to the same location on two of the nights, while the other spent each night in a different location.

Large numbers of C. scripta have been observed leaving the Rio Grande River just prior to flooding and moving across the Santa Ana National Wildlife Refuge (Wayne Shifflett, personal communication), probably in response to the impending changes in the habitat (Cagle, 1944; Webb, 1961). In August, 1976, the water level in Falcon Reservoir was lowered, flooding Santa Ana. Of the 183 turtles marked and released in Willow Lake prior to the flood, none were recaptured during post-flood trapping, indicating that the sudden increase in the water level may have dispersed them into surrounding areas. Moll and Legler (1971) observed the same phenomena during seasonal flooding of Panamanian populations of C. scripta.

Short migrations were noted on two occasions, both involving adult females. One was captured on 21 May 1976 in an irrigation canal along the northern boundary of Santa Ana National Wildlife Refuge, then recaptured on 15 September 1976 in Willow Lake, which lies several hundred meters south of the canal. The second female was first captured on 19 June 1976 in Cattail Lake and then recaptured on 16 September 1976 in Willow Lake, which lies 1.6 km northeast of the original capture site. On several occasions I found C. scripta crossing the refuge roads, indicating that there is an exchange of individuals between populations on the refuge.

Growth

Cagle (1946) detailed the most complete analysis of growth in Illinois populations of C. scripta, and additional information was provided by Cagle (1948, 1950) and Webb (1961). Moll and Legler (1971) analyzed growth in tropical populations of this species.

Summarizing the work of the authors listed above, growth in C. scripta is rapid and variable from hatching through juvenile stages, with the rate of growth slowing as the individual becomes larger, declining to a large extent once the individual reaches sexual maturity (PL=90-100 mm in males and 150-195 mm in females). The size at which sexual maturity is attained does not seem to vary over wide geographical areas (Cagle, 1950), although Webb (1961) felt that females might attain a larger size before reaching sexual maturity in populations of C. scripta in Lake Texoma, Oklahoma. In Panamanian populations, males mature at lengths of 125-135 mm and females at lengths of 250-260 mm (Moll and Legler, 1971). Finally, there are differences in the rate of growth exhibited by populations in different aquatic habitats (Cagle, 1946; Gibbons, 1967, 1970b; Hulse, 1976). This may be a result of food availability (Cagle, 1946; Hulse, 1976) or a function of food quality, i.e. populations with more carnivorous diets exhibited faster growth rates than those with more herbivorous diets (Gibbons, 1967, 1970b; Hulse, 1976).

Growth rates for C. scripta were determined by three methods: 1) plotting the plastron length against the number of growth rings, 2) differences in the measurements of recaptured individuals, where at least 30 days had elapsed between captures, and 3) the relationship of the standard measurements with one another.

Growth rings or "annuli" are the epidermal rings found on the plastral scutes of some turtles, usually being formed during the overwintering process when growth ceases (Cagle, 1946). A detailed description of the formation of these rings was given by Moll and Legler (1971). Until about 5 years of age, one growth ring is deposited annually; however, beyond this period the deposition of these rings becomes quite erratic with two or more rings being deposited in some years, while none at all are deposited in other years (Nichols, 1939; Cagle, 1944, 1952). Secondary growth rings are formed when growth slows or ceases (Moll and Legler, 1971). Cessation of growth may result from food shortages due to floods (Moll and Legler, 1971) or a declining water level (Webb, 1961).

A low correlation (r=.115) was found between the plastron length and the number of growth rings. The study area is subject to periodic flooding, possibly resulting in food shortages, thereby causing the formation of a growth ring (Moll and Legler, 1971). Thus, the number of growth rings may not be an accurate indicator of age, but rather the number of environmental fluctuations that individual has experienced.

Growth rates based on recaptured C. scripta are presented in Table 7. The largest increase in length belonged to the smallest individual. This individual was first captured in an impoundment at Cattail Lake (Santa Ana National Wildlife Refuge) which had little aquatic vegetation. It was recaptured in an adjacent impoundment, which had become flooded due to the water letdown from Falcon Reservoir; this impoundment had a great deal of vegetation in it. The increase in size of this individual may have resulted from an increased availability of food that occurred between the initial and final captures. Cagle (1946) found slightly lower increases in measurements/100 days for individuals from Illinois in the same size classes as those found in Table 7. This may be the result of a shorter growing season in the

Table 7. Percentage increase and growth rate (mm/100 days), in parentheses, of adult <u>Chrysemys scripta</u> from the lower Rio Grande Valley of Texas

INITIAL PLASTRON LENGTH (mm)	SEX	ELASPED TIME (DAYS) BETWEEN CAPTURES	CARAPACE LENGTH	CARAPACE WIDTH	PLASTRON LENGTH	PLASTRON HIND LOBE WIDTH	BRIDGE WIDTH	SHELL DEPTH
106	M	105	7.0% (7.6)	7.7% (6.7)	8.5% (8.6)	9.8% (4.8)	5.3% (1.9)	15.4% (5.7)
178	M	83	1.0% (2.4)	2.7% (4.8)	1.6% (3.6)	3.2% (2.4)	3.5% (3.6)	13.2% (12.0)
207	F	88	3.7% (9.1)	3.0% (5.7)	2.4% (5.7)	4.9% (5.7)	1.3% (1.1)	10.3% (10.2)
211	F	104	4.1% (8.7)	1.9% (2.9)	3.3% (6.7)	4.3% (3.8)	1.3% (1.0)	5.7% (4.8)

northern United States. Cagle (1950) found that the growing season was about 150 days (May-October) in Illinois and about 200 days (April-November) in Louisiana.

Figures 9 and 10 indicate the morphometric relationships of C.s. elegans from the study area. Approximately equal numbers of males and females were used in these analyses.

Food Habits

To date, information on the food habits of C.s. elegans in southern Texas is not available. Stomach content analyses were confined to individuals taken during the summer (21 June to 22 September) months. Because of the small number of juveniles captured, all analyses were confined to sexually mature individuals (determined by plastron length).

Several authors (Parker 1939; Marchand, 1942; Minyard, 1947; Moll and Legler, 1971) have characterized this species as being omnivorous although the principal dietary item was aquatic vegetation. However, there does not appear to be a preference for a particular plant species (Cahn, 1937). Minyard (1947) reported that a population of this species in a barren roadside ditch was utilizing dead plant material which had fallen into the water. Strecker (1927) found that captives would accept meat, fish, grasshoppers, crickets, and sowbugs. Clark and Gibbons (1969) characterized this species as being an opportunistic carnivore.

Marchand (1947) and Clark and Gibbons (1969) found a shift in diet from juvenile to adulthood, with the former being primarily carnivorous while the latter was primarily herbivorous. This shift was

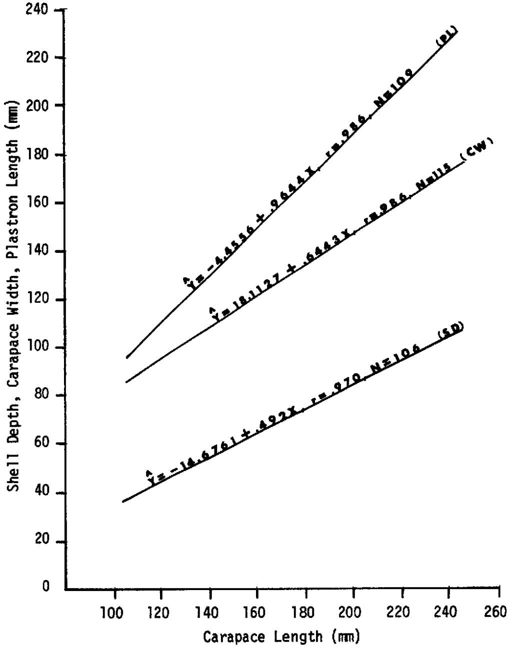


Figure 9. Relationship of three measurements to the carapace length of adult <u>Chrysemys scripta</u> from the lower Rio Grande Valley of Texas. Regression was by the least squares method.

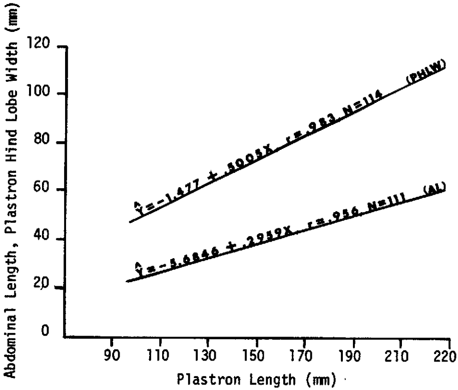


Figure 10. Relationship of two measurements to the plastron length of adult Chrysemys scripta from the lower Rio Grande Valley of Texas. Regression was by the least squares method.

found to occur over the period of one summer (Clark and Gibbons, 1969). Tinkle (1958a) suggested that this dietary shift may be a means of reducing competition, allowing larger populations to exist in a given area. Another possibility may involve selection for a carnivorous diet as a means of promoting increased rates of growth in juveniles, thus shortening the period of time to which they are exposed to predators. Gibbons (1970b) and Hulse (1976) found that populations with carnivorous diets had higher rates of growth, in all age classes, than those with primarily herbivorous diets. As adults, the energy expenditure needed to actively pursue prey might not be balanced by the energy assimilated, particularly since adult turtles are usually at the top of their food chains; therefore, the need to shift to a more sedentary food item (Clark and Gibbons, 1969). In addition, adult females expend more energy on egg production, therefore a primarily herbivorous diet would allow the individual to assimilate large quantities of energy without much expenditure. Moll and Legler (1971) did not find such a pronounced dietary shift in Panamanian populations of this species.

Contrary to results presented in other food habit studies, populations of C.s. elegans in southern Texas appear to be slightly more carnivorous than herbivorous (Table 8). This may be the result of collecting data during only one season of the year. Plant material from three individuals taken from Delta Reservoir (Hidalgo Co.) in May, 1976, was identified as follows: Zannichellia palustris (Zannichelliaceae), Potamogeton pectinatus (Potamogetonaceae), and possibly Ruppia maritima (Potamogetonaceae). The Index of Relative Impor-

Table 8. Results of stomach content analyses of adult *Chrysemys scripta* taken in the lower Rio Grande Valley of Texas (N=10, Total Volume=16.39 ml, No. Food Items=63).

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Plant Material	0.0%	42.7%	50.0%	0.0%
Animal Material				
Invertebrate				
Decapoda	1.6%	1.2%	10.0%	0.0028
Hemiptera	14.3%	0.8%	10.0%	0.0151
Coleoptera	6.3%	0.8%	10.0%	0.0075
Diptera	9.5%	0.2%	20.0%	0.0194
Hymenoptera	23.8%	1.5%	20.0%	0.0506
Unidentified Insects	1.6%	1.4%	10.0%	0.0030
Total	57.1%	7.2%	30.0%	0.1929

Table 8 (continued)

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Vertebrate				
Pisces				
Atherinidae	31.7%	18.9%	10.0%	0.0506
Unidentified	11.1%	9.2%	30.0%	0.0609
Total	42.8%	28.1%	30.0%	0.2127
Unidentified	0.0%	22.9%	40.0%	0.0000
Miscellaneous				
Nematoda	0.0%	0.0%	90.0%	0.0000

tance (IRI) indicates that invertebrate and vertebrate prey items occupy positions of approximately equal importance in the diet of this species. Table 9 indicates that adult males eat more plant and animal matter than do females. However, due to the small sample size, these trends may not hold for the population as a whole.

Basking Behavior

Basking behavior of C. scripta was originally intended to be studied during the period of 13-20 March 1977 at the Headquarters Pond in the Laguna Atascosa National Wildlife Refuge. However, due to a lack of captures and adverse weather conditions, this portion of the study could not be completed. The following discussion is a summarization of information presented by Boyer (1965), Moll and Legler (1971), and Auth (1975) on the basking behavior of this species.

With respect to the relationship between physical factors and basking, light intensity appears to be the most important with there being a direct relationship between the number of basking turtles and the light intensity. Wind velocity has some effect in that it can alter the rate of heat gain, while relative humidity has little or no influence. Water temperature is important in determining the initial air temperature at which basking commences. At elevated water temperatures, turtles prefer basking sites which are partially submerged over those which are completely clear of the water. Water temperature rather than air temperature appears to be more important in inducing turtles to emerge. Basking incidence increases on favor-

Table 9. Comparative stomach content analyses of male and female Chrysemys scripta from the lower Rio Grande Valley of Texas (No. Males=5, No. Females=5, Total Volume=16.39 ml, No. Food Items=63).

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Plant Material				
Males	0.0%	36.0%	80.0%	0.0000
Females	0.0%	6.7%	20.0%	0.0000
Animal Material				
Males	44.4%	43.8%	60.0%	0.5292
Females	55.6%	13.5%	60.0%	0.4146
Miscellaneous				
Nematoda				
Males	0.0%	0.0%	100.0%	0.0000
Females	0.0%	0.0%	80.0%	0.0000

able days which follow a period of unfavorable conditions and then decreases if those favorable conditions continue. Basking frequency is inversely proportional to basking duration.

With respect to biological factors affecting basking, size appears to be the most important factor relating to the time spent basking, with larger individuals basking longer than smaller ones. Sexual differences, except as they relate to size, may be of little importance, although below certain water temperatures, more males bask than do females.

Moll and Legler found that turtles avoided commonly used basking sites when nets were set near them and that they never basked on experimentally anchored logs. During this study, it was observed on several occasions that turtles not only continued using traditional basking sites when nets were set near them, but that they also utilized the styrofoam float associated with the net as a basking platform. Turtles in two locations (Laguna Atascosa and Santa Ana National Wildlife Refuges) exhibited little, if any, hesitancy in utilizing artificial basking sites.

Trionyx spiniferus emoryi (Agassiz)
(Texas Spiny Softshell Turtle)

Distribution and Status of Populations Reported in the Lower Rio Grande Valley

Webb (1962) described the range of this form as the Rio Grande drainage in Texas, New Mexico and northeastern Mexico (Rio San Fernando and Rio Purificacion drainages). This form is also found in the Colorado River drainage of Arizona, New Mexico, and southern Nevada, although its presence is probably the result of human activities (Miller, 1946). This species was caught in all three counties included within the study area and represents a new county record for Willacy County (see Appendix A for localities).

Relative Abundance

Trionyx s. emoryi is generally found in turbid rivers with some current and mud or sand bottoms (Webb, 1962). While present at several localities, this species was never caught in large numbers. Of the three species of aquatic turtles present in the study area, this species was the second most abundant, making up 14.0% of all turtles captured (N=770). The relative abundance of this species at the different study sites within the study area is presented in Table 1. In other parts of its range, this species comprised from 1-16% of the populations in Illinois (Cagle, 1942), 3.9-7.0% in Louisiana (Cagle, 1950; Cagle and Chaney, 1950), and 12% in Lake Texoma, Oklahoma (Webb, 1961). Degenhardt and Christiansen (1974) attribute the infrequent capture of this species to the fact that it occupies an aquatic microhabitat different from that of other turtles.

The abundance of this species varies, but it seems to be more frequent in situations where some current is present. Cagle and Chaney (1950) found that *T. spiniferus* comprised 3.8-31.2% of the captures in areas of quiet water and 25.3-66.6% in streams with some current. Its greater abundance in the latter areas probably stems from its better swimming ability as a result of a depressed shell with a thin, flexible edge, webbed feet, and orientation of the limbs (Cahn, 1937), thereby allowing it to outcompete other species of turtles for resources in this environment. The only site in the study area (Table 1) at which T. spiniferus was caught exclusively, was a stream with a moderate current.

While this species was found in the study area in aquatic situations where there was some current, it was also trapped, observed, or reported to be in many localities of quiet water that were at varying distances from any stream. If this species had a tendency to migrate overland this phenomena could be easily explained, but Cagle (1942) found that this species had less of a tendency to migrate than other turtles. Several possible explanations exist as to why this species is widely distributed throughout the study area. All of Cameron and Willacy Counties and the eastern portion of Hidalgo County form the Pleistocene-Recent delta of the Rio Grande River (Trowbridge, 1932). Before the damming of the river, it meandered through the region, often changing its course which resulted in the formation of resacas and possibly stranding populations of T. spiniferus in them. Other explanations include hurricanes, that flood lowlands to a depth of several feet, allowing these turtles access to many bodies of water; and man-made drainage canals that provide dispersal routes into new areas.

Population Structure and Sex Ratio

Of 114 T. spiniferus caught during this study, measurements were taken on 65 individuals; 83.0% of these were adults. Cagle (1942) found that adults comprised 95% of individuals examined from southern Illinois. The size class frequency of those examined is presented in Figure 11. This species is sexually dimorphic with respect to the maximal sizes attained by adults (Webb, 1962). The largest male examined had a plastron length of 139 mm, while the largest female was 264 mm in length. The average plastron length (and 95% confidence interval) of adult (PL>90 mm) males was 114.6 ± 4.47 mm, that of adult (PL>180 mm) females was 222.7 ± 10.50 mm, and that of juvenile (90<Pl<180 mm) females was 129.9 ± 14.23 mm.

The sex ratio (male:female) of T. spiniferus caught in the study area was 41:73. Breckenridge (1955) found a sex ratio of 71:92 for this species in Minnesota. There is evidence that the method of capture may bias the estimates of different population characteristics of a species (see Conclusion section).

Population Density

Population density of T. spiniferus at one study site is presented in Table 3. Less precise data was gathered at two other locations. Twelve trap nights were accumulated in the Resaca de los Fresnos (Laguna Atascosa National Wildlife Refuge) with four individuals being caught (no recaptures). The traps were set to cover 61 meters of the river, giving an average of 1 T. spiniferus/ 15

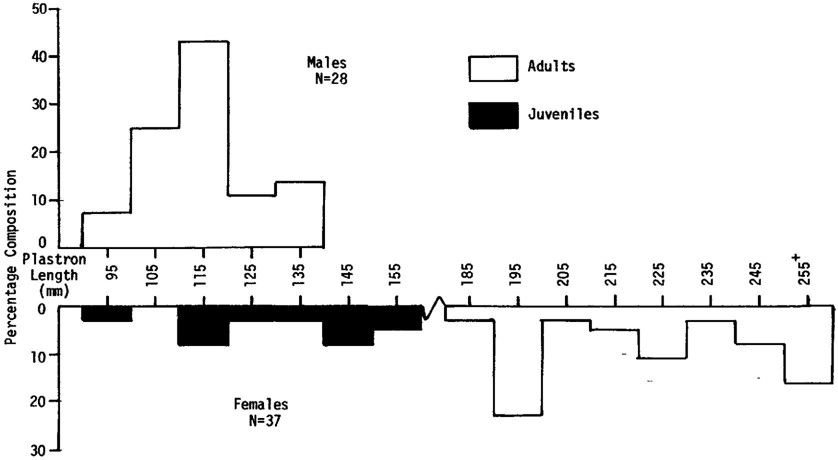


Figure 11. Frequency distribution of the size classes of Trionyx spiniferus examined from the lower Rio Grande Valley of Texas. Explanation of size classes as in Figure 7.

meters. A mark recapture study was conducted along one shore of a resaca on the western boundary of the Bentsen-Rio Grande State Park. An average of the estimates generated by the Lincoln Index and the Schnabel Method (Smith, 1974) gave a rough estimate of 3 T. spiniferus/100 meters of shoreline.

Movements

Aquatic movements of a river population of T. muticus in Kansas have been reported by Plummer and Shirer (1975). Terrestrial movements of T. spiniferus have been reported by Cox (1894) and Newman (1906). Breckenridge (1955) found that T. spiniferus was generally sedentary, although Plummer and Shirer (1975) reported that both sexes of T. muticus make brief, long distance, aquatic forays (males-up to 3510 m, females-up to 7800 m).

Table 3 indicated that prior to the flooding of Santa Ana National Wildlife Refuge, T. spiniferus was not present in Willow Lake; however, after the flooding this species comprised 52% of the captures. The summer of 1976 was the first year that the refuge has been flooded in 2-3 years (George Unland, personal communication), therefore it seems possible that any T. spiniferus present on the refuge after previous flooding may have dispersed out of Willow Lake over a period of time or died form some unknown cause. Cagle (1942) reported that this species has less of a tendency to migrate than other species of aquatic turtles.

Growth

Growth data on _T. spiniferus_ could not be obtained due to a lack of recaptures. There have been few reports in the literature on growth in softshells because there is no easy way to determine age in members of this group, other than by long term studies.

Mitsukuri (1905 in Webb, 1962) reported that hatchling _T. sinensis_ have an average carapace length of 27 mm, and that the average length (carapace) at the end of the first year is 45 mm, the second year 105 mm, the third year 125 mm, the fourth year 160 mm, and at the end of the fifth year 175 mm. According to him, _T. sinesis_ females mature in their sixth year. Breckenridge (1955) constructed a hypothetical growth curve for _T. spiniferus_ in Minnesota. He reported that the average carapace length of females at the end of their tenth year was 9.8 in. (248.9 mm), at the end of the fifteenth year 11.7 in. (297.2 mm), at the end of the twentieth year 13.1 in. (332.7 mm), at the end of the thirtieth year 15 in. (381 mm), and at the end of the fifty-third year 17 in. (431.8 mm). For males, he reported that individuals had a carapace length of 6.25 in. (158.8 mm) at the end of ten years, and 6.75 in. (171.5 mm) at the end of fifteen years.

Figure 12 indicates the morphometric relationships of _T. spiniferus_ from the study area. Approximately equal numbers of males and females were used in this analysis.

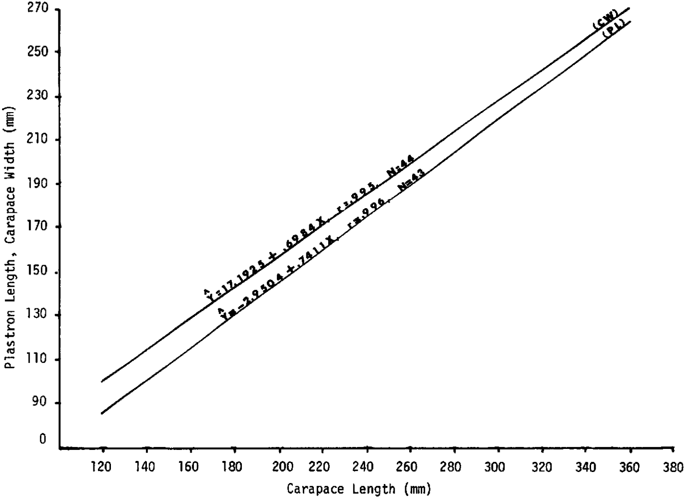


Figure 12. Relationship of two measurements to the carapace length of adult Trionyx spiniferus from the lower Rio Grande Valley of Texas. Regression was by the least squares method.

Food Habits

A number of authors (Evermann and Clark, 1916; Clark and Southall, 1920; Cahn, 1937; Lagler, 1943; Breckenridge, 1944; Penn, 1950; Anderson, 1965) have indicated that crayfish (Cambarus sp.) are the principal component of this species' diet, with aquatic insects and small vertebrate forms making up most of the remainder. Shockley (1949) found that food items consisted mostly of small fish and bottom organisms. Parker (1939) found a large amount of insect remains in the stomachs of two juveniles. The presence of small amounts of aquatic vegetation has been reported by Cahn (1937) and Lagler (1943). Webb (1962) examined the digestive tracts of two adult T. spiniferus emoryi and found that one contained mostly insects and some plant material, while in the other the proportions were reversed. Strecker (1927) reported that captives preferred fish. Wayne Shifflett (personal communication) found the digestive tracts of two T.s. emoryi completely full of newborn Peromyscus sp. The mice had apparently become available as prey items when a low-lying field became flooded.

The results of this study indicated that animal and plant matter are consumed in about equal proportions, although approximately 75% of the plant material obtained came from two females. This suggests that plant material may not be consumed in large quantities by a majority of the population. It appears that the majority of individuals in T. spiniferus populations in southern Texas are primarily carnivorous. The IRI (Table 10) indicates that invertebrate rather than vertebrate prey items make up the bulk of this species' diet.

Table 10. Results of stomach content analyses of adult Trionyx spiniferus taken in the lower Rio Grande Valley of Texas (N=13, Total Volume=25.31 ml, No. Food Items=67).

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Plant Material	0.0%	50.1%	53.8%	0.0000
Animal Material				
Invertebrate				
Odonata	9.0%	0.4%	15.4%	0.0145
Orthoptera	3.0%	0.6%	7.7%	0.0028
Hemiptera	6.0%	0.8%	15.4%	0.0105
Coleoptera	6.0%	11.5%	30.8%	0.0539
Lepidoptera (larvae)	3.0%	0.6%	7.7%	0.0028
Diptera	49.3%	1.3%	30.8%	0.1558
Hymenoptera	6.0%	0.1%	23.1%	0.0141
Unidentified Insects	9.0%	0.1%	23.1%	0.0210

Table 10 (continued)

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Total	91.3%	15.4%	61.5%	0.6673
Vertebrate				
Pisces				
Ictaluridae	1.5%	0.4%	7.7%	0.0015
Unidentified	6.0%	14.4%	30.8%	0.0628
Aves	1.5%	3.2%	7.7%	0.0036
Total	9.0%	18.0%	46.2%	0.1247
Unidentified	0.0%	16.6%	23.1%	0.0000
Miscellaneous				
Nematoda	0.0%	0.0%	15.4%	0.0000

Table 11 indicates that females consume a larger proportion of plant material than do males, although, again, this is the result of a consumption of about 75% of the plant material obtained by two females.

Basking

There have been several reports (Evermann and Clark, 1916; Minton, 1944; Smith, 1961; Webb, 1962) of instances where *T. spiniferus* has been observed basking at favorable sites. All of these observations occurred in areas in the northern United States. Favorable sites included: river banks, lake shores, sand bars, and large boulders in streams. Numbers of turtles observed at any one time ranged from several to many numerous individuals. Cahn (1937) suggested that not all species of *Trionyx* bask to the same degree. Webb (1962) noted that southeastern and southwestern forms bask to a lesser degree than others.

During the course of this study, individuals of this species were observed basking on only three occasions. All three sightings occurred on objects located in the water.

Kinosternon flavescens flavescens (Agassiz)
(Yellow Mud Turtle)

Distribution and Status of Populations Reported in the Lower Rio Grande Valley

This form ranges from southern Nebraska and eastern Colorado, south through Kansas, Oklahoma, Texas, eastern New Mexico, and south-

Table 11. Comparative stomach content analyses of adult male and female Trionyx spiniferus from the lower Rio Grande Valles of Texas (No. Males=5, No. Females=8, Total Volume=29.35 ml, No. Food Items=67).

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Plant Material				
Males	0.0%	7.1%	80.0%	0.0000
Females	0.0%	45.3%	37.5%	0.0000
Animal Material				
Males	46.3%	18.6%	100.0%	0.6490
Females	53.7%	29.0%	62.5%	0.5170
Miscellaneous				
Nematoda				
Males	0.0%	0.0%	20.0%	0.0000
Females	0.0%	0.0%	12.5%	0.0000

ern Arizona and into northern Mexico with isolated colonies in western Arizona (Conant, 1975). This species was caught in all three counties included within the study area and represents a new county record for Willacy County (see Appendix A for localities).

Relative Abundance

Kinosternon flavescens was the species captured the least during this investigation, making up 2.0% of all captures (N=770). This species was not taken in large numbers, but this may not accurately reflect its abundance since kinosternids are difficult to trap, even in areas where they are known to be abundant (Cagle and Chaney, 1950). A case in point is given by Cahn (1937), who first reported this species in the Illinois River in 1931, even though the Illinois State Natural History Survey had been working the area since 1870. Ortenburger and Freeman (1930) and Marr (1944) reported that this species was one of the most abundant turtles in Oklahoma and Kansas, respectively. However, their results are based on seining rather than trapping. *Kinosternon* sp. made up only 0.7% of the captures in Louisiana (Cagle, 1950) and 2.0% in Oklahoma (Webb, 1961). *Kinosternon flavescens* exhibits a decided preference for shallow pools with mud bottoms in xeric grasslands (Minton, 1958; Mahmoud, 1969; Anderson, 1965).

Several individuals were found on roads after heavy rains. All of these locations were in areas where the road was bordered by grassland. Only two individuals trapped in the study area were not taken in a grassland area (farm tank and the subtropical habitat at Santa

Ana National Wildlife Refuge), the remainder were taken from ponds or roads in the coastal prairie (Laguna Atascosa National Wildlife Refuge). While only one individual was collected in Hidalgo County, this species is not uncommon there (Frank Judd, personal communication).

Population Structure and Sex Ratio

Numbers of *K. flavescens* trapped were too small to permit an accurate estimate of population composition. The size class frequency of those taken in the study area is presented in Figure 13. The largest individual had a plastron length of 122 mm, with an average plastron length (and 95% confidence interval) of 111.1 ± 4.92 mm for all adults (CL>80 mm). Only adults were caught in traps.

The adult sex ratio (male:female) was 13:0 for individuals collected in the study area. Cahn (1937) reported a sex ratio of 15:1 for captures from Illinois. Mahmoud (1960) found that adults from Oklahoma populations had sex ratios of 64:88, 23:35, and 20:13. There is evidence that the method of capture may bias the estimates of different population characteristics of a species (see Conclusions section).

Population Density

Estimates of the population density of *K. flavescens* from different study sites are given in Table 3. Population densities for kinosternid turtles, as reported in the literature, are given in Table 12. Ortenburger and Freeman (1930) reported an average of

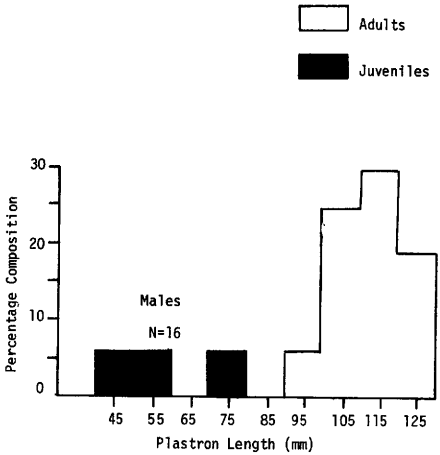


Figure 13. Frequency distribution of the size classes of *Kinosternon flavescens* taken in the lower Rio Grande Valley of Texas. Explanation of size classes as in Figure 7.

Table 12. Population densities for various species of kinosternid turtles as reported in the literature.

SPECIES	LOCALITY	DENSITY (nos./ha)	SOURCE
Sternotherus odoratus	Indiana	36	Wade and Gifford, 1974
	S. Carolina	17	Gibbons, 1970a
	Oklahoma	149	Mahmoud, 1969
Sternotherus carinatus	Oklahoma	229	Mahmoud, 1969
Kinosternon subrubrum	Oklahoma	159-258	Mahmoud, 1969
Kinosternon flavescens	Oklahoma	28	Mahmoud, 1969
	Texas	4	This Study

1 K. flavescens/100-200 ft. (30.5-61 m) of roadside ditch in Oklahoma. Mahmoud (1969) estimated that males had an activity area of about 0.26 acres (0.11 ha) and females about 0.31 acres (0.13 ha).

Movements

Frequent overland migration is characteristic of this species (Mahmoud, 1969). Of the K. flavescens collected in the study area, 25.0% were found on roads after heavy rains. Mahmoud (1969) found that rainy days induced sporadic activity in Oklahoma populations. All of the road captures were males, which may be explained by the fact that for periods of less than 100 days, males have average first-last capture distances 1.45 times larger than those of females (Mahmoud, 1969).

Growth

Growth of K. flavescens has been documented by Mahmoud (1969). As in C. scripta, K. flavescens has a variable growth rate, with juveniles having a higher rate of growth than adults (Mahmoud, 1969). Both sexes mature at a carapace length of 80-120 mm (Mahmoud, 1967). This species is limited to about a 90 day growth season in Oklahoma, with other kinosternids having growth seasons ranging from 170-190 days (Mahmoud, 1969).

Growth rates of individual K. flavescens in the study area could not be determined as a result of a lack of recaptures and the obliteration of the growth rings on one or more plastral scutes. I examined individuals of this species from the Texas Cooperative Wildlife Collection to obtain some information on growth of this species in Texas. A growth curve was calculated and is presented in Figure 14. Mahmoud (1969) calculated a similar curve in Oklahoma populations.

Figures 15 and 16 indicate the morphometric relationships of *K. flavescens* from Texas. Approximately equal numbers of females and males were used.

Food Habits

Mahmoud (1968) found that this species is a bottom feeder and that prey items were composed chiefly of insects (27.8% by volume), crustaceans (27.7% by volume), and mollusks (23.5% by volume), with amphibians, carrion, and aquatic vegetation making up the remainder. Cahn (1937) reported finding a large amount of vegetation in the stomach of a female, while Minton (1958) reported this species feeding on carrion and aquatic invertebrates. Jameson and Flury (1949) suggested that this species feeds on *Ambystoma* larvae. Mahmoud (1960) found this species feeding on eggs of *Ambystoma texanum*, minute crustaceans (Conchostracidae), and tadpoles. Strecker (1927) reported that captives would accept meat, but preferred insects and small mollusks.

The sample size for this species was too small to make any definite observations on food habits of populations in southern Texas. However, it appears that they have diets (Table 13) similar to populations in Oklahoma (Mahmoud, 1968).

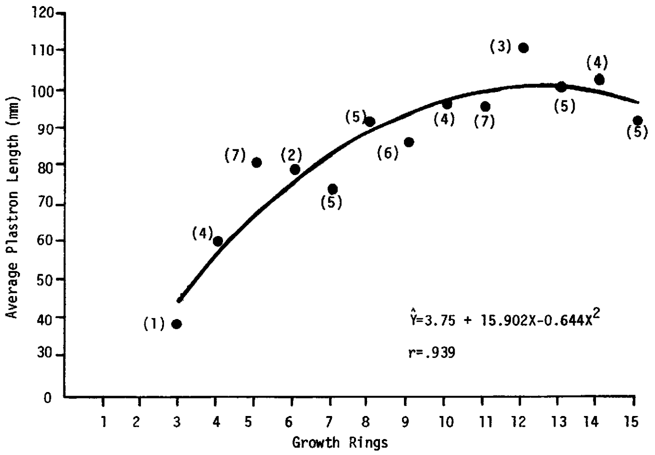


Figure 14. Growth curve for Kinosternon flavescens from Texas. Numbers in parentheses indicate the sample sizes. Regression was by the least squares method.

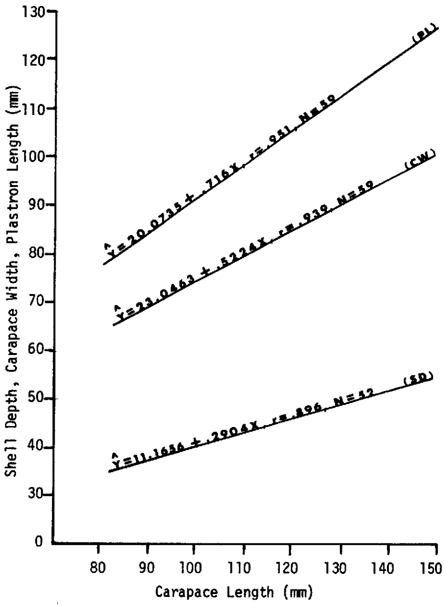


Figure 15. Relationship of three measurements to the carapace length of adult <u>Kinosternon flavescens</u> from Texas. Regression was by the least squares method.

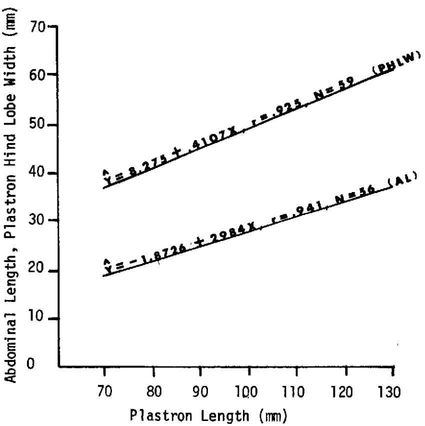


Figure 16. Relationship of two measurements to the plastron length of adult Kinosternon flavescens from Texas. Regression was by the least squares method.

Table 13. Results of stomach content analyses of adult <u>Kinosternon flavescens</u> taken in the lower Rio Grande Valley of Texas (N=4, Total Volume=0.72 ml, No. Food Items=4).

Food Item	Numerical Percentage	Volumetric Percentage	Frequency Percent	Index of Relative Importance
Plant Material	0.0%	0.0%	0.0%	0.0000
Animal Material				
Inverebrate				
Decapoda	25.0%	11.1%	25.0%	0.0903
Gastropoda	50.0%	86.1%	25.0%	0.3403
Coleoptera	25.0%	2.8%	25.0%	0.0695
Vertebrate	0.0%	0.0%	0.0%	0.0000
Miscellaneous				
Soil	0.0%	0.0%	50.0%	0.0000

Basking Behavior

Mahmoud (1960) found that this species basks only occasionally during the spring and autumn and is "photophobic" during the summer. He found that the activity period shifted from a diurnal cycle in the spring and fall to that of a crepuscular cycle in the summer. Captures made during the late morning or early afternoon were made on overcast days or in shaded portions of the study area (Mahmoud, 1960). Conant (1975) indicated that this species may bask while floating at the water's surface. Individuals of this species were not observed basking during this study.

CONCLUSIONS

Effects of Sampling on the Estimation of Population Characteristics

Many of the assumptions associated with mark-recapture methods are known to be erroneous. One of these assumptions, equal probability of capture for any member of the population, has been shown to be particularly in error. Several investigators (Geis, 1955; Huber, 1962; Ream and Ream, 1966; Eberhardt, 1969; Summerlin and Wolfe, 1973) have demonstrated that the probability of capture is influenced by sex, age, social status, method of trapping, and environmental factors.

With respect to turtles, it has been found that different methods of trapping bias the results with respect to size class frequencies, sex ratios, numbers, and kinds of turtles caught (Ream and Ream, 1966; Gibbons, 1970a). Turtles that have been "marked" tend to be warier than those which haven't been marked (Tinkle, 1958b; Sexton, 1959; Moll and Legler, 1971; Brown, 1974). The longer individuals are disassociated from their natural environment, the more likely they are to migrate (Pearse, 1923). Furthermore, trap response is known to be affected by bait selection, method of set, water temperature, water depth, availability of food, water turbidity, current phase of the annual cycle, and whether or not other captures are conspecifics (Cagle, 1942, 1950; Cagle and Chaney, 1950).

When the number of recaptures is low, as was the case in this study, traditional methods of estimating population size using proportions, such as the Schnabel Method or Lincoln Index, tend to overestimate the size of the population. Edwards and Eberhardt (1967) compared various methods of estimating population size on a known population and found that the two best methods involved either plotting a regression line against the frequency of capture on semi-log paper or by using the Maximum Likelihood Equation ($\hat{N}$=no. marked/ 1-[no. marked/no. captured]). Plotting Brown's (1974) frequency of capture data on a semi-log plot gave an estimate of 140-150 individuals in a population of Terrapene coahuila. This figure is in general agreement with his estimate of the population size utilizing several other different methods. Employing Brown's data in the Maximum Likelihood Equation gives an estimate which is slightly higher than the mean estimate of several methods utilized by him (Brown, 1974: Table 12). In their comparisons, Edwards and Eberhardt (1967) were using data from populations where the number of captures approached 50% of the total number caught. No method of estimating turtle populations may be accurate until the number of recaptures is about 50% of the total number caught or there are individuals in the population which have been captured five or more times, as in Brown's (1974) study. Considering the wariness of turtles once they have been handled, other techniques may have to be developed to estimate the size of the population. Ream and Ream (1966) suggested that a combination of collecting by hand and using basking traps to catch turtles may give the best results.

Sex ratios of turtles from different populations in the study area varied considerably from 1:1. It has already been mentioned that the method of sampling can influence the sex ratio of captures.

Other explanations include: 1) improper methodology (Gibbons, 1970c), 2) seasonal changes in activity which result in the aggregation of large mostly unisexual groups (Cagle, 1952), 3) selective survival of one sex in small isolated populations.

The overall sex ratio of C. scripta taken during my study was about 1:1. However, the ratios of T. spiniferus and K. flavescens varied considerably. In the case of the former, it was probably a result of improper methodology, i.e. the assignment of immature females as males, and in the case of the latter, it was probably a result of the sampling method and the fact that males move farther distances than females over short periods of time.

Comparative Population Structure and Density

The population structure of each of the three species in the study area (Figures 7, 11, 13) indicate a high proportion of adults. This may have been a result of the method of sampling the population; however, turtles have been characterized as having stable populations with long-lived individuals and little recruitment. Populations with this type of age structure have a Type III survivorship curve (Pearl, 1928 in Krebbs, 1972). Richmond (1965) discussed this type of population and indicated that in order to establish a population of this nature, a species must possess two characteristics: 1) a marked decline in the mortality rate near the period of sexual maturity, and 2) a long reproductive life when compared to the developemental period. Life history studies of turtles (Woodbury and Hardy, 1948; Cagle, 1950; Legler, 1960b; Moll and Legler, 1971) indicate that these vertebrates fulfill both requirements.

Populations of C. scripta achieved the highest densities of any species of turtle in the study area. This phenomena has been attributed to the fact that this species can tolerate crowding, has omnivorous food habits, and will remain in an area even though there is little food available (Cagle, 1950).

In post flood trapping at Santa Ana National Wildlife Refuge, the capture ratio of C. scripta and T. spiniferus was approximately 1:1 (Table 3). Since these turtles presumably came from the Rio Grande, one may speculate that these two species are in approximately equal abundance in the river.

Comparative Food Habits

Although the three species of turtles examined in this study generally eat the same food items, they do so in varying proportions. Unless otherwise noted, all figures referred to in the following discussion are the volumetric percentages. Plant material was found to comprise 42.7% of the diet of C. scripta, while it made up 52.1% in T. spiniferus (75% of this plant material came from two individuals). Plant material was not found in individuals of K. flavescens examined, but it made up 8.5% of the diet of Oklahoma populations (Mahmoud, 1968).

Invertebrate prey items made up 7.1% of the food items found in C. scripta, 13.6% in T. spiniferus, and 100% in K. flavescens. The

IRI indicates that the two most important invertebrate prey items for each of these species are Hymenopterans and Dipterans in C. scripta, Dipterans and Coleopterans in T. spiniferus, and Gastropods and Decapods in K. flavescens. The IRI also indicates that invertebrates are about 3.3 times more important in the diet of T. spiniferus than in C. scripta.

Fish were the most common of the vertebrate prey items, making up 28.1% of the diet of C. scripta and 17.1% in T. spiniferus. The IRI indicated that vertebrates are about 50% more important in the diet of C. scripta than in T. spiniferus. Vertebrate prey items were not found in any of the K. flavescens examined, although Mahmoud (1968) found that they made up 8.9% of the diet in Oklahoma popula- ions.

Basking Behavior

Basking is a characteristic habit of most aquatic turtles. There have been several theories advanced as to the function of this behavior, including: 1) as a means of increasing the rate of digestion (Cagle, 1950); 2) as a means on inhibiting algal growths and external parasites (Cagle, 1950) and facilitating ecdysis (Moll and Legler, 1971); and, 3) as a means of synthesizing Vitamin D (Pritchard and Greenhood, 1968 in Moll and Legler, 1971).

Boyer (1965) did not find any correlation between feeding and basking, although Minyard (1947) found a positive correlation between ambient temperature and feeding. Several investigators (Cagle, 1950; Moll and Legler, 1971: Ernst, 1972; Auth, 1975) either suggested or found a positive correlation between ambient temperatures and basking. Cowles and Bogert (1944) suggested that the maintenance of normal digestive processes may be temperature dependent, i.e. putrefiaction of food occurs when individuals are kept at low temperatures where digestive enzymes cannot function. Riddle (1909), Kenyon (1925), Chesley (1934), Abbott (1941), and Wright et al. (1957) found that enzyme activity and the rate of digestion increase with temperature.

Cagle (1950) found that captives which were not allowed to bask developed severe inflammations. Neill and Allen (1954) suggested that drying may allow turtles to rid themselves of algae. Moll and Legler (1971) found a general inverse correlation between basking and the number of leeches present on an individual. Basking may allow scutes which are about to be shed to dry out, thus facilitating their removal (Moll and Legler, 1971). Sexton (1965) found that the numbers of individuals shedding reached a peak in mid-summer.

Pritchard and Greenhood (1968 in Moll and Legler, 1971) speculated that the function of basking was to promote the synthesis of Vitamin D by the action of UV light on skin sterols. However, this theory was based on limited observations (1 day) and, by their own admission, on tenuous reasoning.

In summary, the function of basking is probably twofold: 1) to increase the rate of digestion, enabling an individual to compete for whatever resources are available, and 2) the drying out of the shell and integument contributes to the overall health and well-being of that individual.

Effects of Man on Turtle Populations in the Lower Rio Grande Valley

Man is the single most important factor influencing the distribution and abundance of turtles in the study area. Heatwole (1966) reviewed changes in the distribution and abundance of the herpetofauna in Panama as a result of man's activities. The most injurious of these activities is that of habitat destruction through urbanization, farming, and ranching. Using data from Trowbridge (1932) and the 1974 Texas Almanac, it was calculated that the population density of Willacy County in 1970 was about 33 times that of 1920, that of Cameron County about 6 times, and that of Hidalgo County about 5 times. One of the major facets of farming in the study area is irrigation. The 1975 Texas Almanac stated that 9.6% of the land in Willacy County was being irrigated, 30.5% in Cameron County, and 43.5% in Hidalgo County. Recently, the voters in Hidalgo and Willacy Counties passed a bond election providing for the construction of a drainage canal with a 153 m right-of-way from Hidalgo County through Willacy County to the coast. One of the activities associated with the construction of this canal will be the draining of nearby ponds via small feeder canals. While the canal will drain some habitat, it will also provide new habitat for those displaced individuals.

Associated with farming is the effect of introduced chemical substances on turtle populations. Farmers in the study area rely heavily upon airborne application of pesticides for control of plant competitors and insect pests. Herald (1949) suspected that the cause of death of several turtles was the ingestion of DDT contaminated fish. A resident farmer noted that the number of turtles in his pond always declined after spraying, although he never saw a dead one. Ferguson (1963) observed the same phenomena in Mississippi.

Numerous studies have demonstrated the effect of DDT and other pesticides on avian reproductive success by causing thinning of the eggshell. Culley and Applegate (1967) noted that lizard eggs had higher concentrations of DDT than did the female's body tissues. Pesticides are concentrated in the fat tissues of the females (Culley and Applegate, 1967) and the fat bodies are associated with reproduction (Hahn and Tinkle, 1965). Several investigators (Meeks, 1968; Pearson et al., 1973; Owen and Wells, 1976) have found that fat tissues in turtles concentrate pesticides more than do other body tissues. However, turtles' longevity appears to be relatively unaffected by ingestion of these substances as evidenced by the low mortality rate in various studies (Ferguson, 1963; Pearson et al., 1973, Owen and Wells, 1976). This may be the result of a low metabolic rate in reptiles (Coulson and Hernandez, 1964). Stickel (1951) and Ferguson (1963) reported the effects of pesticides on box turtle populations. In the former study, no significant differences in growth or population size were observed. However, due to wind drift and a heavy canopy cover, only a small amount of the original application reached the ground. The latter study noted that one box turtle probably died from heptachlor poisoning, although numerous others did not appear to be harmed. While pesticides may contribute to a decline in the viability of turtle eggs, the flexible chelonian egg shell may not be affected at all, as opposed to the rigid avian egg shell. What effect pesticides have on the developing turtles is unknown.

Other activities which affect turtle populations include highway mortality, "shootin' heads," and the removal of individuals for human consumption. In conjunction with the first factor, the numbers of turtles killed increases with highway mileage in an area and the three counties in the study area have a combined total of more than 2800 miles of road. Over a 19 year period (1940-1959), the average number of T. ornata/mile on a 100 mile stretch of road in Missouri declined from about 1/mi. to 0.16/mi., probably as a result of the populations adjacent to the road becoming depauperate (Anderson, 1965). With respect to human consumption, softshells, in particular, are prized, although in other parts of its range, C. scripta serves as a food source (Heatwole, 1966; Moll and Legler, 1971).

In addition to aquatic turtles, there are two terrestrial species reported from the study area, Gopherus berlandieri and Terrapene ornata (Raun and Gehlbach, 1972). During this study, I found the largest concentration of Gopherus to be at the Laguna Atascosa National Wildlife Refuge with only one observed at Santa Ana National Wildlife Refuge. Auffenberg and Weaver (1969) noted that the changeover from ranching to field crops in the majority of the study area destroyed large tracts of habitat.

During this same period, I did not observe any Terrapene, although a few have been recently observed in the study area (Forrest Mitchell, personal communication). George Unland (Assistant Refuge

Manager, Laguna Atascosa National Wildlife Refuge) grew up near Santa Ana National Wildlife Refuge and remembers seeing them as a boy, but not recently. Blanchard (1923) attributed the decline of box turtles in Iowa to the intensive agricultural practises of that area.

In conclusion, man's effects on turtle populations in the study area are both harmful and helpful. Habitat destruction reduces the amount of land that terrestrial forms have to maintain their populations. However, the construction of water projects increases the area that aquatic forms have to maintain their populations.

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APPENDIX A

Localities in Willacy County, Texas, at which *Chrysemys scripta elegans*, *Trionyx spiniferus emoryi*, and *Kinosternon flavescens flavescens* were caught.

Chrysemys scripta elegans

On FM 1420, 16.73 km north of FM 508

On FM 1420, 1.77 km north of FM 498

On FM 498, 10.30 km west of FM 1420

0.40 km north of Hwy 186, 11.58 km east of Hwy 77

Las Majadas Ranch, pond east of owner's house

On Hwy 186, 1.93 km east of Hwy 77 (Las Majadas Ranch)

On Hwy 186, 30.09 km east of Hwy 77

On FM 498, 1.77 km west of FM 1520

On FM 2099, 2.09 km south of Hwy 186

On FM 490, 1.61 km east of Hwy 77

100 m north of FM 490, 2.01 km east of Hwy 77

Intersection of Hwy 77 and FM 490, SE corner

On FM 498, 0.32 km west of FM 2099 (north)

On FM 498, 0.80 km east of FM 2099 (north)

On FM 2099, 0.72 km south of FM 498

On FM 2099, 1.05 km south of FM 498

On FM 2099, 0.64 km south of FM 498

On FM 2629, 0.16 km east of Hwy 77

On FM 2099, 1.45 km south of FM 498

On FM 1018, 1.13 km west of FM 2099

On FM 490, 1.93 km west of FM 1015

On FM 1015, 2125 km south of FM 490

Trionyx spiniferus emoryi

On FM 498, 0.80 km east of FM 2099 (north)

On Hwy 186, 1.93 km east of Hwy 77 (Las Majadas Ranch)

On FM 2099, 2.09 km south of Hwy 186

Reservoir north of FM 408, between Rio Hondo and FM 507

Arroyo Colorado at Arroyo City

Arroyo Colorado at FM 506

Kinosternon flavescens flavescens

Las Majadas Ranch, owner's house (1.9 km east of Raymondville)

On Fm 498, 0.32 km west of FM 2099 (north)

VITA

Eric Kevin Grosmaire was born in Troy, New York, on 11 April 1948, the son of Leon A. Grosmaire and Nan Marsh Gosmaire. He graduated from White Station High School, Memphis, Tennessee, in June, 1966, and attended Memphis State University for one year before joining the United States Marine Corps in 1967. Mr. Grosmaire was released from active duty in 1970. He received a Bachelor of Science degree in Zoology from Florida Technological University, Orlando, Florida, in June, 1975. In September, 1975, he entered the graduate school at Texas A&M University. Mr. Grosmaire has attended several scientific meetings and has presented a paper at one of them (Southwestern Association of Naturalists).

The typist for this thesis was Jackie Highfill.