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Range, Habitat Use, and Seasonal Activity of the Yellow Mud Turtle (*Kinosternon flavescens*) in Northwestern Illinois: Implications for Site-Specific Conservation and Management

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ABSTRACT. – The yellow mud turtle (*Kinosternon flavescens*) is a xerothermic relict partially distributed among several disjunct populations on sand prairies along the former Prairie Peninsula in Illinois, Iowa, and Missouri. In Illinois, where the species is listed as endangered, the largest known population occurs at the northeastern extent of the species' range in Henry County. A major portion of the site is in private ownership, and the Illinois Department of Natural Resources seeks to acquire additional mud turtle habitat to supplement a 1998 acquisition that was designated as a preserve. To determine additional preserve acquisition area, identify critical habitat, and recommend management techniques, data regarding the range, habitat use, and seasonal activity of turtles at this location were collected through radiotelemetry, aquatic trapping, and drift fence captures. Eleven adult mud turtles (6 males, 5 females) were fitted with radiotransmitters and tracked between 12 May 1992 and 6 June 1993. Radiotagged turtles occupied ephemeral ponds between mid-April and late May, and aestivated in sand dunes in June and July. Some emerged for a second aquatic activity period in the ponds in July and August. Hibernation occurred in sand dunes from September through mid-April. Aquatic trapping and drift fence captures of adults and juveniles confirmed similar schedules of activity, aestivation, and hibernation observed in the telemetered individuals. Drift fence captures of hatchlings indicated emergence from nest locations from early May through June. A lack of hatchling captures in mid-summer suggests that hatchlings remained in ponds or dried pond beds through the summer. Important aquatic habitat identified during the study included shallow ponds with soft, muddy substrates and dense emergent vegetation; important terrestrial habitat included sand dunes with an elevation of at least 15 feet above the ponds. Telemetered adult mud turtles burrowed into sand dunes at locations of up to 90 m from pond edges. Females oviposited at nest locations up to 70 m from pond edges. Nest predators included coyotes (*Canis latrans*), striped skunk, (*Mephitis mephitis*), and western hognose snake (*Heterodon nasicus*). The recommended area for the preserve addition includes a buffer of terrestrial habitat to a distance of 90 m from maximum pond level edges. Additional preserve design recommendations include constructing a bridge or culvert under a road that bisects the site so that turtles can move between aquatic and terrestrial habitats on each side of the road, and encouraging native shortgrass prairie vegetation in acquired areas. Other recommendations include periodic introductions of hatchling mud turtles from a nearby, appropriately identified population, predator management techniques that encourage hatchling recruitment, and conducting habitat management activities with the potential to disturb soils between November and March.

KEY WORDS. – Reptilia; Testudines; Kinosternidae; *Kinosternon flavescens*; turtle; endangered species; conservation; management recommendations; range; critical habitat; seasonal activity; preserve size; radiotelemetry; predation; nesting; hibernation; aestivation; ephemeral ponds; sand hills; xerothermic relict; Illinois

This study is an analysis of certain aspects of the natural history of the yellow mud turtle (*Kinosternon flavescens*) in Illinois (Fig. 1), where the species is listed as endangered (Illinois Endangered Species Protection Board 1999), which will aid in the conservation of the largest known population in the state. The purpose of the research was to determine minimum preserve size and develop management recommendations for promoting optimal health of critical habitat within the preserve based upon the movements of free-ranging turtles, their use of habitat, and their seasonal activity periods.

The main part of the range of *K. flavescens* encompasses regions of the North American Southwest and Great Plains, from Nebraska, Kansas, and Oklahoma to Mexico. But in the Midwest it persists as a xerothermic relict that invaded the region along what has been termed the "Prairie Peninsula" (Transeau 1935), a region of grassland/steppe habitat that extended east from the Great Plains of North

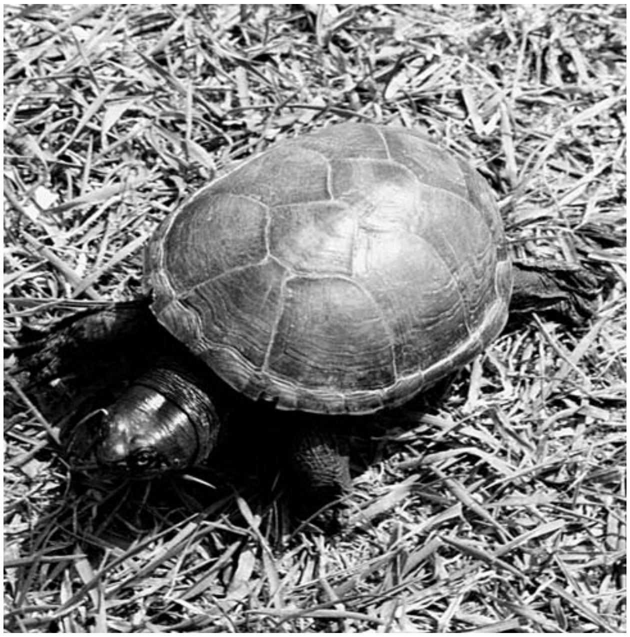

Figure 1. Adult male *Kinosternon flavescens* from the Henry County study site in Illinois.

America during a climatically dry period following the Wisconsinan glacial retreat. A number of western species were able to expand their ranges eastward along this corridor, including *K. flavescens* (Smith 1957). At the close of the Xerothermic Interval, a cooler, moister climate returned to much of eastern North America, and by 4000 years ago many xeric-adapted species were eliminated. Certain western species were able to persist in xeric habitats such as sand prairies, which drain well, and thus, mimic desert conditions. *Kinosternon flavescens* thus persists as disjunct populations in northeast Missouri, southeastern Iowa, and northwestern Illinois within the Mississippi River basin, and along the Illinois River basin in central Illinois (Dodd 1983; Bickham et al. 1984; Christiansen et al. 1990; Fig. 2). Due to the rarity of yellow mud turtles in the region, the species is listed as endangered in these three states.

The disjunct populations of yellow mud turtles in Illinois, Iowa, and Missouri were formally afforded subspecific status by Smith (1951), who called the group *K. f. spooneri* following a morphometric analysis. The validity of this designation, however, has been debated over the years. Iverson (1979a) was the first to assess the legitimacy of the taxonomic designation; his statistical analysis of a suite of morphological characters provided evidence that the subspecific designation was valid. Using a larger sample size (216 vs. Iverson's [1979a] 24), Houseal et al. (1982) placed *K. f. spooneri* in synonomy with *K. f. flavescens* based upon morphological characters. Similarly, Berry and Berry (1984) placed *K. f. spooneri* in synonomy with *K. f. flavescens*, also based upon morphological characters. Phylogenetic evidence provided by Serb et al. (2001) showed that the isolated populations of *K. flavescens* in Illinois, Iowa, and Missouri were genetically similar to *K. f. flavescens* populations in the Great Plains when compared with *K. f. arizonense* and *K. f. durangoense*. The similarities, the authors contended, pointed to both a recent separation from populations in the Great Plains (around 4000 years), and a suite of natural history traits that do not contribute to high rates of genetic differentiation (Serb et al. 2001). They suggested, however, that more detailed genetic analyses of *K. f. flavescens* could determine whether a subspecific designation would be appropriate for the midwestern populations (Serb et al. 2001). A subspecific ranking would more easily allow for these populations to become listed and protected under provisions of the Endangered Species Act of 1973. Therefore, despite that past attempts to list these populations under the Endangered Species Act have failed (see Dodd 1982), future analyses may again open up the possibility for federal protection.

The largest known population of yellow mud turtles within the state of Illinois occurs within the Green River drainage basin (a tributary of the Mississippi River) in northwestern Illinois, at the northeastern extent of the species' range (Fig. 2). Previous studies at this site have identified the presence of a population from which more than 100 turtles, most of which are adults, have been captured and marked since 1978. Because of the large number of turtles recorded at this site in relation to other *K. flavescens* sites in Illinois, and because of the relatively unmodified state of the habitat that supports the population, the site holds the greatest potential for the continued survival of a viable population of the species within Illinois.

The Endangered Species Protection Board, a division of the Illinois Department of Natural Resources (IDNR), commissioned the study described in this paper in 1991. The purpose of the study was to determine the extent of movements made by turtles between aquatic and terrestrial habitats, and to identify critical areas and important habitats used by the turtles. These data were to be used to determine which portions of the study site—which was completely within private ownership—should be purchased from each of the two primary landowners to create a preserve for the turtle population, as well as to provide directions for future management of the site. Establishing a preserve would protect critical mud turtle habitat at this locale, particularly habitat crucial for reproduction and resource acquisition activities, and aestivation and hibernation refugia. The study was conducted between May 1992 and June 1993. In 1998, a portion of the site was purchased from one of the landowners by the IDNR and designated as a state nature preserve. Efforts to acquire additional areas of the study site have been ongoing with the other landowner since the study was completed, but have thus far failed. The IDNR remains extremely interested in acquiring portions of the property from this landowner. Findings and recommendations from the current study should, therefore, provide the IDNR with important data to prioritize their acquisition of critical areas and the direction of management once additional areas have been acquired.

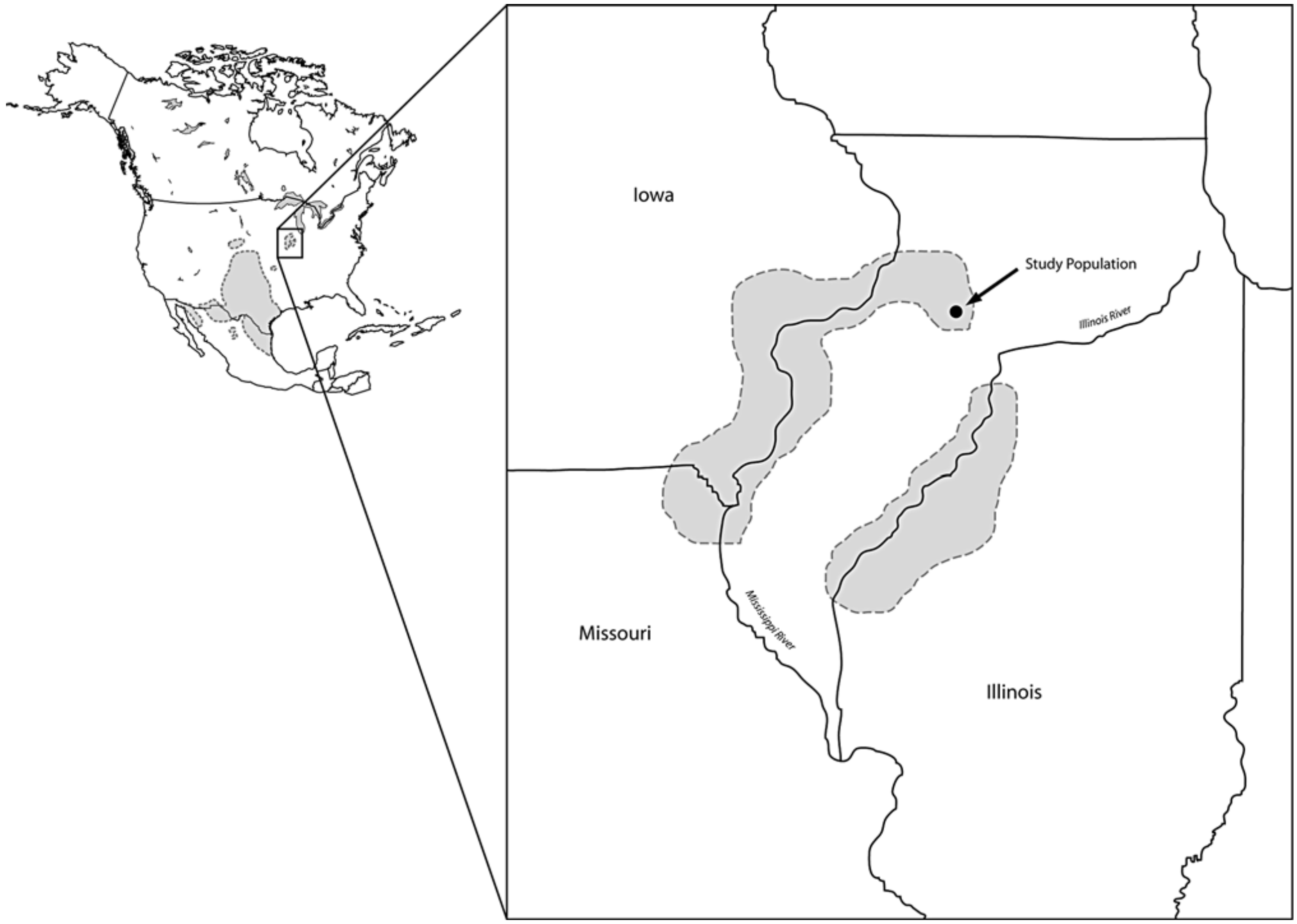

Figure 2. Distribution of *Kinosternon flavescens* and location of the Henry County study population.

METHODS

Site Description. — The site, which is located in a portion of the former Green River Lowlands, is characterized by low-lying areas supporting a complex of ephemeral ponds, surrounded by rolling sand hills (Figs. 3 and 4). Soils within the pond depressions are Orio loam, a soil that drains at a moderately slow rate; the majority of the sand hills surrounding the ponds consist of Oakville loamy fine sand, which drains rapidly (Elmer et al. 1980). The water levels within the pond complex were quite variable throughout the duration of the study. During 1992, water levels were relatively high in early May, but the ponds had dried completely by the end of the second week of June. They remained dry until heavy rains increased water levels during the first and second weeks of July. During the spring of 1993, exceptionally heavy rainfall flooded the area, and Ponds 2–8 merged into one large, continuous body of water, and Ponds 1 and 9 expanded in size considerably. When pond water levels were maintained for extended periods, dominant emergent aquatic vegetation included water smartweed (*Polygonum amphibium*), water pepper (*P. hydropiperoides*), sedge (*Carex comosa*), and spikerush (*Eleocharis obtusa*). Dense patches of mulberry (*Morus* sp.) and willow (*Salix* sp.) populated the edges of the larger ponds; these were kept small due to grazing by cattle. A variety of invertebrate and vertebrate species occupied the ponds for at least a portion of their life cycles, including Oligochaete worms, ramshorn snails (*Helisoma anceps*), dragonflies and damsel flies (Odonata), mayflies (Ephemoptera), aquatic beetles (Dytiscidae and Hydrophilidae), a variety of flies (Diptera), tiger salamanders (*Ambystoma tigrinum*), green frogs (*Rana clamitans*), bullfrogs (*Rana catesbieana*), leopard frogs (*Rana pipiens*), cricket frogs (*Acris crepitans*), chorus frogs (*Pseudacris triseriata*), gray tree frogs (*Hyla versicolor*), American toads (*Bufo americanus*), snapping turtles (*Chelydra serpentina*), Blanding's turtles (*Emydoidea blandingii*), painted turtles (*Chrysemys picta*), and muskrats (*Ondatra zibethicus*).

The terrestrial habitat surrounding the pond complex is characterized by low, rolling sand hills or dunes to a maximum elevation of approximately 13 m above the level of the ponds. At the time of the study, vegetation on the dunes differed between the two parcels and was dependent on land use. Terrestrial habitat within the property east of the pond complex (Parcel A) was characterized by shortgrass prairie dominated by bunch-forming grasses (*Schizachyrium scoparium, Sporobolus cryptandrus, Stipa spartea*, *Koelaria cristata*). The owner of this parcel

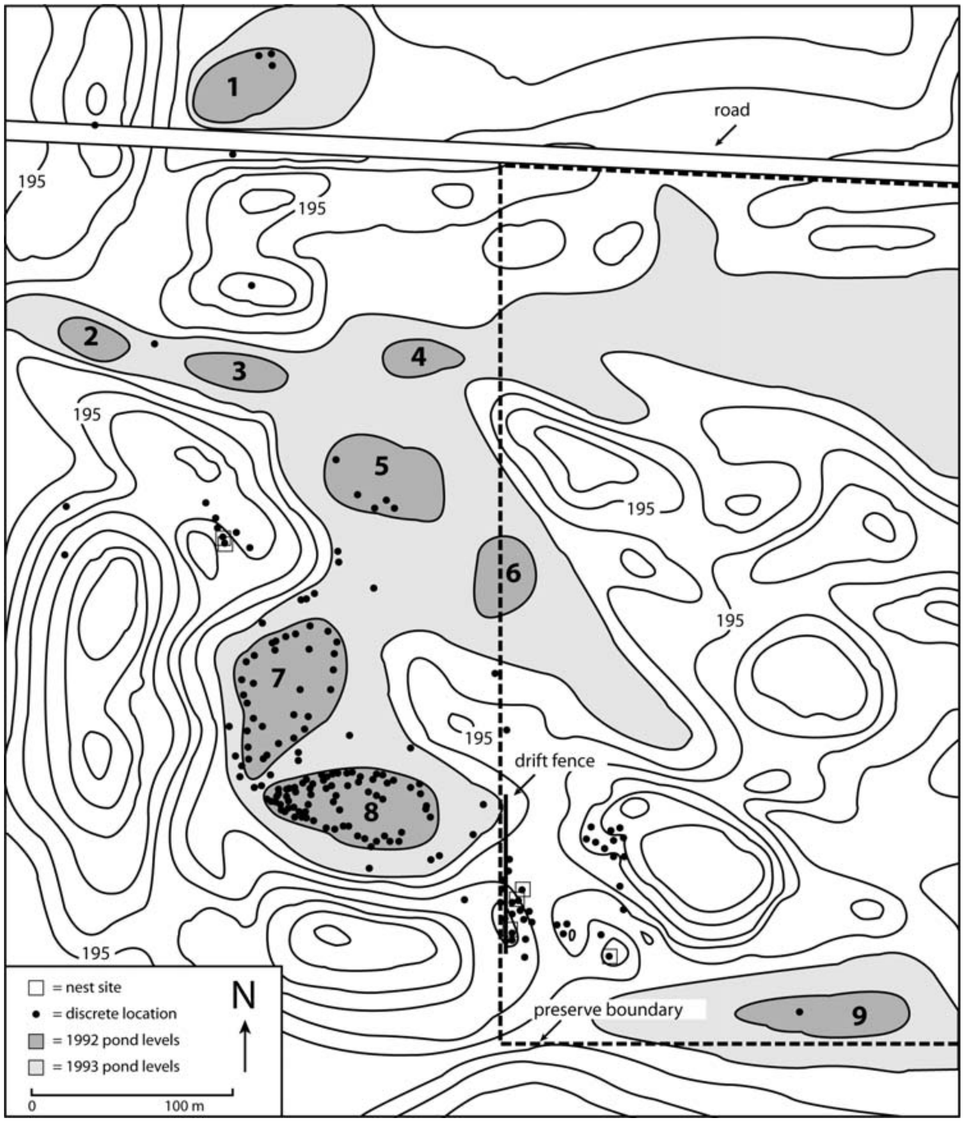

Figure 3. Map of the Henry County yellow mud turtle study site. Dots indicate discrete locations for telemetered mud turtles; open squares represent nest sites. The approximate location of the current preserve boundary (Parcel A) is indicated on the east side of the map. Parcel B is located outside of the preserve to the west. The pond levels are indicated for the average pond levels in 1992 (Ponds 1–9) and the maximum pond level in April and May 1993. The drift fence is located at the boundary of Parcels A and B. Contour interval is 5 feet; the 195-foot contour is indicated.

occasionally grazed a small herd (< 30) of cattle over the relatively large area, but it was not intensive enough to negatively affect the quality of the habitat there. The land surrounding the north, west, and south of the pond complex (Parcel B) was under different ownership, and land use consisted of intensive grazing of a large herd (> 100) of cattle over a relatively smaller area. Terrestrial vegetation in this parcel consisted primarily of sod-forming introduced grasses (especially *Poa pratensis* and *Agrostis alba*) that were continually kept short due to the intensive grazing. Additional grazing areas were located to the north of the pond complex. Areas further to the west and south were primarily agricultural fields; to the east, the shortgrass prairie transitioned to a white oak savannah. A rural blacktop road bisects the northern portion of the pond complex (Fig. 3).

Data Collection Methods. — Turtles were captured using aquatic hoop traps baited with chicken livers, through drift fence trapping, and by hand from 11 May 1992 to 12 June 1993. During the 1992 season, turtles were captured in aquatic hoop net traps when water levels of the small ponds were sufficiently deep (between 20 and 40 cm) for use of the traps. Trapping was limited to ponds 1–9 in the complex (Fig. 3); previous trapping efforts outside of the pond complex revealed that mud turtles did not inhabit these areas. A drift fence, 75 m in length, was positioned between the ponds and a large sand dune situated east of the pond complex, and a total of 33 5-gallon bucket traps and 15 1-gallon coffee can traps were buried along both sides of the fence. The fence was placed along the western border of Parcel A (Figs. 3 and 4); permission to place drift fences in other areas of the study

Figure 4. Panoramic photograph of a portion of the study site showing the eastern side of Pond 8 and the sand dune area east of the pond complex. The drift fence (aluminum flashing) is visible along the border of Parcels A and B. View is to the northeast from the sand dune south of Pond 8.

site was denied by the owner of Parcel B, who cited concerns that his cattle could fall and injure themselves in the drift fence or bucket traps. Turtles were captured in the drift fence when exiting the ponds for aestivation and hibernation, and when leaving aestivation and hibernation sites to enter the ponds. To supplement the data regarding movements of turtles between the ponds and dune areas to the north, south, and west of the pond complex, intensive field searches were performed in Parcel B during periods when increased activity was observed along the drift fence. Captured turtles were uniquely marked by notching marginal carapace scutes. Age was estimated through observation of major growth annuli on plastral scutes.

Eight adult turtles (5 males, 3 females) were fitted with radiotransmitters (L&L Electronics, Mohomet, IL) and movements were tracked beginning 12 May 1992 until 6 June 1993. An adult female hand-captured in a shallow terrestrial burrow was radiotagged on 7 July 1992, and her movements followed through April 1993. Two additional adult turtles (1 male, 1 female) were tracked from 8 May to 6 June 1993. The radiotransmitter packages—including the transmitter, battery, antenna, and waterproof epoxy casing—weighed approximately 10 to 12 grams each, which is approximately 3%–4% of the body weight of an adult turtle. After being fitted with a transmitter, each turtle was released at the point of capture within 24 hours. Movements were monitored daily from initial date of capture to 12 August 1992, weekly from 12 August to 10 October 1992, monthly from 10 October 1992 to 1 April 1993, and weekly from 1 April to 6 June 1993. Location, behavior (including nesting), and habitat were recorded during relocations of the telemetered turtles. The locations of the tracked turtles and nests were digitized on a map of the study area to determine the area and habitats they used. Additionally, periods of activity and inactivity were recorded in an effort to determine the range and timing of activity periods of adult turtles in this population. Nesting data were collected from telemetered females during the appropriate season; as females moved from terrestrial burrow locations to ponds or other terrestrial locations, their previous burrow was carefully excavated in an attempt to locate nests. Additional nesting data were recovered from nontelemetered females by noting the locations of other nests discovered during intensive daily surveys of the study site throughout the nesting season.

RESULTS

Aquatic Habitat Use. — In the aquatic environment of the pond complex, radiotagged turtles were almost always found associated with emergent vegetation in shallow water (8–40 cm deep) during aquatic activity periods. From mid-May to August 1992, and late May to early June 1993, actively foraging turtles were exclusively located at shallow pond edges amongst dense emergent vegetation ($n = 115$). In late April and early May 1993, turtles were also located at shallow pond edges, but were basking ($n = 4$) or moving slowly ($n = 9$) rather than actively foraging.

During the activity periods in the ponds, soft, muddy substrate was also an important habitat component. All radiotagged individuals in observance ($n = 5$) burrowed into the muddy substrate for 1 to 4 days prior to exiting the ponds for aestivation. On 2 occasions, telemetered individuals burrowed into the pond substrate on cool, overcast or rainy days as well. Two individuals burrowed into the pond substrate in the 2-week period following emergence from hibernation. Deeper portions of ponds (> 60 cm) were utilized in the 2-week period following hibernation as well ($n = 5$).

Terrestrial Habitat Use. — The sand hills surrounding the pond complex were used for aestivation, nesting, and overwintering sites. Upon exiting the ponds, the radiotagged turtles burrowed into slightly elevated locations in the sand hills. The majority of aestivation and hibernation burrow locations (43 of 48, 90%) were located at elevations greater than about 5 m above the level of the ponds. The radiotagged turtles preferred burrowing into areas of sparse vegetation. Burrowing turtles were located in areas of relatively sparse prairie vegetation in 44 of 48 (92%) observations. In four instances, burrows were made through thick grass sod, but the turtles had less success burrowing in these areas.

Six mud turtle nests were observed during the 1992 nesting season, including 5 oviposition sites used by 3 radiotagged females and 1 site used by 1 nontelemetered turtle. Two of the telemetered females split their clutches between 2 separate nest sites (see Tuma 1993). All nest sites were located on sand dunes within 70 m of the pond edges (1992 levels), and at least 5 m above the level of the ponds (Fig. 3). The nest sites were excavated in areas of sparse vegetation and ranged in depth from 10 to 20 cm. Predators destroyed all nests observed during the 1992 season. One nest was preyed upon by a western hognose snake (*Heterodon nasicus*), whereas the remaining 5 were preyed upon by mammalian predators, including 1 by striped skunk (*Mephitis mephitis*) and 4 by coyote (*Canis latrans*). The coyotes appeared to be attracted to the smell of the turtles during the nesting season rather than the smell of the eggs, as numerous mud turtles, including males, were unearthed from their burrows by coyotes in mid- to late June 1992 in an apparent effort to locate nest sites.

Ranging Area. — Six adult male mud turtles and 5 adult female mud turtles were tracked by radiotelemetry for a total of 3051 tracking days. During this time, the turtles were tracked to 211 discrete locations, including 145 locations in aquatic habitat and 66 locations in terrestrial habitat, during 457 separate observations (Table 1). Most ($n = 144$; 99.31%) of the tracked locations to aquatic habitat were located in Parcel B outside of the current preserve. Furthermore, most ($n = 135$; 93.10%) locations of telemetered turtles in aquatic habitat were located in Ponds 7 and 8 (1992) or in aquatic habitat near these ponds (1993). Discrete terrestrial locations included aestivation or hibernation burrow sites ($n = 48$), locations within the drift fence ($n = 13$), and locations of turtles on the ground surface in transit between burrow sites or ponds ($n = 4$). Most ($n = 34$; 70.83%) of the terrestrial burrow locations were within Parcel A, the current preserve; the remainder ($n = 14$; 29.17%) were located in Parcel B outside of the current preserve area. All terrestrial burrow locations were located between 35 and 90 m of maximum pond level edges.

Aquatic trapping data augmented ranging data obtained from telemetered mud turtles. Aquatic traps were positioned in ponds between 11 May and 12 June, and again from 7 July to 18 August 1992; the ponds were completely dried between these 2 periods. During the first trapping period, 5 of 6 mud turtle captures were from Ponds 7 and 8. The remaining capture was from Pond 5. Just 1 mud turtle was captured during the second trapping period; this individual was trapped from Pond 7.

Seasonal Activity

Radiotagged turtles exhibited seasonal behaviors that included emergence from overwintering burrows in mid-spring, basking in ponds in mid- to late spring, active feeding in ponds during late spring and early summer, aestivation and nesting in sand dunes during mid-summer, reemergence for feeding in ponds in late summer, and overwintering in fall, winter, and early spring within the sand hills.

Emergence from Hibernation. — The study was initiated after turtles had exited hibernation in the spring of 1992; however, emergence from hibernation was documented during the spring of 1993, when 9 radiotagged individuals exited their overwintering burrows and entered the ponds. Emergence dates ranged from 29 April to 24 May 1993. During the 2-week period following emergence in 1993, adults were observed basking in shallow (8–20 cm) water ($n = 4$), burrowing into pond substrate ($n = 2$), occupying the deepest water (> 1 m) in the central portions of the ponds ($n = 5$), or slowly moving along pond edges ($n = 9$).

Spring Aquatic Foraging Period. — During the spring aquatic foraging period, when water temperatures approached 18°–20°C, telemetered turtles were observed actively foraging along pond edges on warm, clear days between sunrise and sunset. During the 1992 season, radiotagged turtles were observed actively foraging from 12 May until 3 June 1992. Active foraging behaviors were also observed in the late spring and early summer of 1993, when radiotagged turtles were actively foraging in ponds between 17 May and 6 June.

Aestivation Period. — All radiotagged turtles left the ponds during mid-summer 1992 and entered aestivation sites by burrowing into the sand dunes surrounding the ponds. Five telemetered turtles (4 males, 1 female) that were captured in ponds in early May 1992 began aestivation by 3 June. Two additional adult females were fitted with transmitters after being captured in the drift fence as they exited ponds for aestivation on 27 May. During aestivation, most individuals remained within relatively shallow burrows (5–25 cm depth) and most turtles remained active throughout the aestivation period. Turtles frequently moved to new burrow sites, and movement within burrows was also evident. Some individuals were observed peering out of shallow burrows through a small hole made by pushing their heads through the sand. This behavior, as well as movements to new burrow locations, occurred most often during overcast or rainy conditions. For 26 observations of movement to new burrow sites during aestivation, 18 (69%) occurred during overcast or rainy conditions. A Chi-square analysis indicated that movements to new burrow sites were significantly more likely during these conditions (Chi-

Table 1. Radiotracking dates, and numbers of tracking days, observations, and discrete locations, for adult male and adult female mud turtles.

Turtle	Radiotracking dates	No. of tracking days	No. of observations	No. of discrete locations	
Males				Ponds	Dunes
L2R2	5–19–92 to 6–6–93	383	61	15	1
L9	5–21–92 to 6–6–93	381	58	8	8
L1L2L3	5–12–92 to 5–24–93	377	47	34	4
L1R2	5–14–92 to 5–24–93	375	71	23	7
L1L2	5–12–92 to 7–19–92	68	26	8	4
L1R10	5–12–93 to 6–6–93	25	5	5	0
Subtotal for males		1609	268	93	24
Females					
L3R3	5–21–92 to 6–6–93	381	64	8	9
L9R9	5–27–92 to 5–24–93	362	54	14	9
L9R8	5–27–92 to 5–24–93	362	56	21	18
L8R2	7–7–92 to 4–29–93	308	10	7	3
L2R1	5–8–93 to 6–6–93	29	5	2	3
Subtotal for females		1442	189	52	42
Total (males and females)		3051	457	145	66

square = 3.846, $p < 0.05$). Seven of the 8 (87.5%) remaining movements that occurred during clear weather were by gravid females prior to egg deposition.

During the entire aestivation period, the number of burrows occupied by females (mean = 9.0, $n = 3$) was significantly greater than that of males (mean = 3.4, $n = 5$, $t = 3.01$, $p < 0.05$). Twenty-two of the 24 (92%) relocations to new burrow sites by radiotagged females ($n = 3$) during aestivation occurred prior to egg deposition, which occurred between 14 and 27 June. Distances moved between burrow sites for all turtle relocations during aestivation ranged from 1.5 m to 178 m (mean = 29.19 m, s = 41.44 m, $n = 35$). However, during the 10-day period before and during egg deposition, distances moved to new burrow sites by the radiotagged females were smaller, ranging from 1.5 to 29 m (mean = 11.9 m, $n = 15$), significantly shorter than movements by aestivating males and females outside of this 10-day period ($t = 2.4$, $p < 0.05$).

Summer Aquatic Foraging Period and Reentry to Burrows. — Five of 9 radiotagged individuals, including 3 males (60% of the male sample) and 3 females (75% of the female sample), entered the ponds for a second aquatic activity period between 8 and 27 July 1992. One of these females emerged for a third aquatic activity period from 10 to 25 September. Individuals that exited aestivation burrows for a second or third activity period in the ponds returned to the same slope of the same dune for hibernation that they used for aestivation. The hibernation sites for these turtles were remarkably close, within 2 to 5 m of the original aestivation sites. One male that did not enter the ponds for a second activity period overwintered in the same burrow used for aestivation. This telemetered male remained in one burrow location for 11 months (25 May 1992 to 29 April 1993). Two other turtles (1 male, 1 female) that did not return to the ponds for a second aquatic activity period moved to new burrow sites in August 1992 following heavy rainfall.

Hibernation Period. — The turtles maintained relatively shallow burrows (mean = 64 cm, $n = 2$) in early October 1992 and began to dig deeper (mean = 116 cm, $n = 3$) during hibernation in late October through December. An adult female excavated on 28 November was located 107 cm below the ground surface, where sand temperatures were 4.4°C. The sand was wet to a depth of approximately 90 cm, but was dry where the turtle was located. Another adult female was excavated on 26 December; this individual was located approximately 119 cm below the ground surface, where the sand temperature was 3.8°C. The frost zone extended to a depth of approximately 30 cm below the ground surface.

Drift Fence Seasonality Data. — Drift fence captures of adult mud turtles augmented seasonality data obtained through radiotelemetry. The drift fence, which was in position from 11 May 1992 to 12 June 1993, resulted in 30 captures of 19 adults (10 females, 9 males). Drift fence captures confirmed the seasonal movements of aestivating turtles during the 1992 season. Five adults (3 males, 2 females) were captured in the drift fence as they exited the ponds for aestivation sites in the dunes between 27 May and 3 June. Five adults (4 males, 1 female) were captured in the drift fence between 4 June and 27 July while they were moving to new burrow locations in the dunes. Females, more often than males, appeared to enter the ponds for a second activity period. Four adult females were captured in the drift fence as they emerged from the dunes for a second activity period in the ponds between 9 and 27 July. Three adults (1 male, 2 females) were captured as they exited from a second activity period in the ponds for a hibernation site in the dunes between 3 and 14

August. Finally, 1 radiotagged female exited the ponds on 31 July and was captured in the drift fence, but returned to the ponds upon her release. Drift fence captures also provided details of the timing of emergence from hibernation in the spring of 1993. Emergence from hibernation began on 19 April and peaked on 29 April, when 9 mud turtles were captured in the drift fence as they left the sand dunes and moved toward the ponds. Overall, males emerged from hibernation to enter the ponds slightly earlier than females, as 3 males were captured between 19 and 21 April, and 8 females were captured between 29 April and 8 May.

Drift fence captures of subadult, juvenile, and hatchling mud turtles provided additional seasonal activity data for younger age classes. Twelve captures of 11 individuals (1 subadult male, 3 juveniles, 7 hatchlings) were made. All of the hatchlings were captured in the drift fence as they exited nest sites and traversed to the ponds between 11 May and 30 June 1992. No hatchlings were observed exiting the ponds for aestivation or hibernation; however, two 1-year-old juveniles were captured on 30 August 1992 as they exited the ponds to enter the dunes for hibernation. One juvenile mud turtle (a 2-year-old) was captured as it exited the ponds on 27 May 1992 for aestivation, and recaptured on 15 June 1992 as it exited the dunes for a second activity period in the ponds. Finally, 1 subadult male (a 6-year-old) was captured on 4 May 1993 as it exited its hibernation burrow in the dunes to enter the ponds.

DISCUSSION

Area of Utilization. — The sand hills within the current preserve area were the location of most of the terrestrial burrow locations by radiotagged mud turtles in the current study; however, a considerable portion of terrestrial sites, including aestivation and hibernation burrows and nest sites, were located outside of the current preserve boundaries. The vast majority of locations of radiotagged turtles within aquatic habitat were located outside of the current preserve area. Radiotelemetry data, as well as aquatic trapping data, indicated that Ponds 7 and 8 were the most important aquatic locales.

The radiotelemetric ranging data collected in the current study was biased towards sampling of mud turtles that utilized the dune area to the east of the ponds because of the sampling bias produced by the location of the drift fence. Because a portion of the radiotagged mud turtle sample was captured in the drift fence, the observed ranging data may be shifted slightly to the east, favoring turtles that utilized the dunes to the east of the pond complex. Turtles that utilized dunes to the south, west, and north of the complex, therefore, may have been underrepresented in the current study. However, based on observations of the terrestrial behaviors of observed turtles, coupled with observations made during numerous surveys across the entire study area, the dune complex to the east was the most heavily used by mud turtles at the site. This area was historically under different ownership and has a history of relatively less intensive use compared to the area outside of the current preserve area. The more-intensive agricultural use of the land in Parcel B outside of the current preserve area, including plowing and cattle grazing, likely provided an inhospitable terrestrial environment for mud turtles. These practices may have resulted in nest site destruction, mortality of turtles aestivating in shallow burrows, and development of a thick, hard turf over the surface of the dunes, resulting in decline of use of these areas by mud turtles.

Mud turtles in this study exhibited site fidelity to burrow locations in the dunes east of the pond complex, returning to the same area to aestivate and hibernate. In all instances, radiotagged individuals that entered ponds for a second aquatic activity period returned to hibernate in approximately the same location as their original aestivation burrow. Iverson (1991) also reported fidelity to migration paths between aquatic resources and sand hills for yellow mud turtles in Nebraska. Aestivation and hibernation site fidelity might help to explain why the dune area to the east of the pond complex was so intensively utilized by mud turtles, while degraded dune areas outside of the current preserve were largely ignored by the turtles.

Habitat Use. — Critical aquatic habitat used by telemetered turtles at the study site included shallow ephemeral ponds with dense emergent aquatic vegetation, and soft, muddy substrate. These data contrast somewhat with aquatic habitat utilization at other locations as noted by Christiansen et al. (1985) and Brown and Moll (1979), who reported that, in addition to temporary ponds, semipermanent or permanent ponds were used. At a location in northeast Missouri, Kofron and Schreiber (1985) reported a large population of yellow mud turtles utilizing a man-modified, leveed pond within a former marsh. Data from other portions of the range of *K. flavescens* indicate that this species can apparently adapt to varying aquatic habitats. Arizona mud turtles (*K. flavescens arizonense*) in Arizona and Sonora were commonly found in temporary, man-made ponds (Iverson 1989a), and yellow mud turtles in Oklahoma occupied both temporary ponds within grasslands, and permanent, man-made farm ponds (Mahmoud 1969).

Critical terrestrial habitat included sand dunes with an elevation of 5 to 13 m above the level of the ponds, covered with sparse vegetation. These areas provided optimal nesting, aestivation, and hibernation sites. The use of terrestrial habitat in elevated areas in sandy soil is consistent with data from eastern Iowa, where hills containing deep, sandy, well-drained soils, and sparse vegetation were identified as important habitat (Christiansen et al. 1985). The shortgrass prairie vegetation characteristic of the area within the current preserve boundaries appears optimal for terrestrial mud turtle habitat. The vegetation in this area of the study site, which was dominated by little bluestem (a bunch grass), was sparse enough to allow mud turtle burrowing, yet dense enough to prevent erosion. Bunch grasses and other sparse herbaceous vegetation were determined to be an important terrestrial habitat component for nesting *K. baurii*; this type of vegetation resulted in lower daily high temperatures and shorter periods of high temperatures in the surrounding soils, which is probably critical for the development of clutches of *K. baurii*, a species that does not bury its eggs as deep as larger aquatic turtles (Wilson 1998). The same habitat component may be important to *K. flavescens* for similar reasons.

Seasonal Activity. — Radiotagged adult mud turtles exhibited fairly clearly defined and predictable seasonal behaviors. In particular, the timing of movements within and between aquatic and terrestrial habitats was patterned. The basic behavioral pattern for adult turtles was hibernation in fall, winter, and early spring; activity in ponds from mid-spring to early summer; aestivation in dunes during mid-summer; and activity in ponds in late summer.

Emergence from hibernation burrows within the sand dunes occurred in mid-spring, when mud turtles traversed to the ponds for courtship and feeding. Drift fence data indicate that males entered the ponds before the females, possibly to establish territories in which to receive females for courtship and breeding. No breeding behaviors were observed during this study; however, data from Iowa (Christiansen et al. 1985) indicate that mud turtles court in ponds in early May following emergence from hibernacula. Mud turtles in this study, as well as turtles from Big Sand Mound (Christiansen et al. 1985), were observed basking and moving slowly or sluggishly along shallow pond edges following emergence from hibernation. In mid- to late May, the turtles began an active period of feeding as water temperatures reached temperatures between 18° and 20°C. These data compare well with data from northeast Missouri, where Kofron and Schreiber (1985) reported that feeding activity in mud turtles commenced when water temperatures reached 18°C and data obtained by Mahmoud (1969), who reported that yellow mud turtles actively fed when water temperatures were between 18° and 32°C.

The aquatic activity period was followed by a return to the dunes for aestivation and nesting. During the 1992 season, the aestivation period began as pond water levels dropped. Aestivation was characterized by burrowing beneath the sandy soil in the dunes to a maximum depth of 25 cm. Adult turtles, particularly pre-nesting females, were active during the aestivation period, frequently moving to new burrow sites, and moving within shallow burrows. Pre-nesting females likely moved to new burrow sites more frequently in an attempt to locate suitable oviposition sites. A significant portion of the adult population returned to the ponds for a second brief period of feeding. Most turtles that returned for second or third periods of feeding in the ponds were females, as indicated by radiotelemetry and drift fence capture data. It is possible that females returned to feed more often than males to replenish resources allocated towards egg production and nesting; however, more research will be needed to determine whether this is the case. Additional feeding periods were followed by a return to the dunes for hibernation. Hibernation was characterized by burrowing beneath the frost line into dry sand where winter temperatures were approximately 4°C.

Weather patterns, particularly rainy or overcast days, had bearing on turtle behavior within both aquatic and terrestrial habitats. Mud turtles foraged continually during clear weather, but typically burrowed into the pond substrate on overcast or rainy days. Conversely, aestivating mud turtles typically remained inactive during clear weather, and moved to new burrow locations during overcast or rainy conditions. Terrestrial movements by yellow mud turtles and other *Kinosternon* species during overcast or rainy conditions is a well-documented behavior (Wygoda 1979; Iverson 1979b, 1989a, 1989b; Christiansen et al. 1985; Meshaka and Blind 2001). The timing of terrestrial movements by nesting female *K. subrubrum* in South Carolina (Burke et al. 1994) and *K. baurii* in south Florida (Wilson et al. 1999) was related to the timing and amount of rainfall; however, no such pattern of movement by nesting females was observed in the current study.

The drift fence capture data enabled not only confirmation of the adult pattern of seasonal activity by adult turtles, but also an assessment of activity patterns of hatchlings, juveniles, and subadults. Drift fence data indicated that hatchlings emerged from nest sites the following spring and summer to enter the ponds. Likewise, Christiansen and Gallaway (1984) observed that yellow mud turtle hatchlings emerged from nests the following spring. Yellow mud turtle hatchlings in Nebraska were observed burrowing below the nest cavity to depths of 41 to 66 cm in October following hatching (Costanzo et al. 1995). Long (1986a) suggested that yellow mud turtles in Texas also overwintered in nests, and emerged the following spring after periods of rainfall. He suggested that the high lipid stores observed in mud turtles eggs (Long 1986b) might enable hatchlings to survive underground until the following spring (Long 1986a). Costanzo et al. (1995) reported that hatchling yellow mud turtles were not tolerant of freezing, suggesting that hatchlings must burrow below the frost line (to at least 71 cm) to survive. Costanzo et al. (2001) reported high desiccation resistance of overwintering hatchlings, an attribute that likely allows them to survive in dry sand below the frost line. Drift fence data from the current investigation seem to suggest that hatchlings do not aestivate, but instead remain in the ponds (or dried pond beds) until late summer (late August to early September), when they emerge (as yearlings) to hibernate in the dunes. Further research will be necessary to confirm this behavior. In their second year, juvenile mud turtles apparently take on the adult pattern of aestivation in the dunes, followed by a second activity period in the ponds. They continue this pattern until they reach adulthood.

Radiotelemetry and drift fence capture data indicate that the period of activity of yellow mud turtles at this Henry County site ranged from mid-April to late September. At any point during this season, however, turtles may be present in both aquatic and terrestrial habitats. Even when immatures and adults were aestivating in the dunes, hatchlings were presumably present in the ponds or dried pond beds. The aquatic habitat is devoid of mud turtles only during the hibernation period (late September through mid-April).

Results from the present study were consistent with those reported by Christiansen et al. (1985), including periods of emergence from hibernacula, utilization of aquatic habitat, aestivation behavior, and emergence from aestivation for a second period of aquatic habitat by some individuals. Aestivation is a behavior common for some species of *Kinosternon* (see Iverson 1989a for review) and is a behavior that presumably evolved in unpredictable arid environments. Yellow mud turtles inhabiting permanent water in New Mexico did not aestivate (Christiansen and Dunham 1972), but turtles in Oklahoma (Mahmoud 1969), Iowa (Christiansen et al. 1985), Arizona and Sonora (Iverson 1989b), and Nebraska (Iverson 1990) aestivated regardless of the presence of permanent water. Long (1985) reported that carcass lipid stores of *K. flavescens* are higher than those of any other turtle studied, allowing this species to remain dormant for extended periods during drought conditions. This is an especially important adaptation for this species, which frequently inhabits environments with ephemeral aquatic environments, as is the case for the current study area.

Management Considerations

The data from the current investigation have particular relevance for determining the amount of land and types of habitats necessary for optimal preserve design at the Henry County yellow mud turtle site. Recommendations for preserve size and design and the direction and timing of management techniques are provided here. Since the initiation of the study in 1992, the IDNR has acquired a portion of the study site that included some terrestrial habitat near the pond complex from one of the landowners. The other landowner, who owns the pond complex and adjacent terrestrial areas, has thus far refused offers from the IDNR. Therefore, although the fieldwork for the current investigation was completed over a decade ago, the data continue to have important and relevant implications for the conservation of the mud turtle population there today.

Preserve Design. — The current preserve protects terrestrial habitat that was identified as important to the mud turtle population; however, most important aquatic habitat is located outside of the current preserve boundaries. The most important and heavily utilized area outside of the current preserve is the large pond complex, particularly the southern extent of the complex where Ponds 7 and 8 are situated west of the drift fence (see Fig. 3). Most telemetered mud turtle locations, as well as most aquatically trapped turtles, were located in this area, which continued to hold water in early summer 1992 when all other ponds in the area had long since dried. Other important areas outside of the current preserve included the large dune located west of Pond 7, where a radiotagged female aestivated, hibernated, and nested, and other ponds throughout the complex, including Pond 1, located north of the road. Radiotelemetry data indicate the significance of the aquatic habitat outside of the current preserve area and punctuate the importance of the acquisition of this area for the protection and management of critical mud turtle aquatic habitat there. It is therefore recommended that, minimally, the area that includes the maximum observed level of the pond complex and a terrestrial buffer that extends 90 m from the maximum pond level edges be acquired for additional preserve land (Fig. 5). This area would include 100% of the observed locations of telemetered mud turtles, as well as 100% of the observed nest locations. This recommended terrestrial buffer around the ponds compares well with data presented by other researchers regarding the use of terrestrial habitat by other *Kinosternon* species. Burke and Gibbons (1995) examined the use of terrestrial habitat by *K. subrubrum* in South Carolina and determined that a 73-m buffer around pond edges was required to contain 90% of terrestrial locations. Buhlman and Gibbons (2001) reported that *K. subrubrum* occupied terrestrial refugia at locations up to 135 m from wetland edges. Wilson et al. (1999) examined the nesting habits of *K. baurii*, and reported that nest locations ranged from 60 to 180 m from pond edges.

Telemetered mud turtles crossed the blacktop road to access Pond 1. Roads are known to be a significant source of mortality for turtles, especially species that make considerable movements over terrestrial habitat (Gibbs and Shriver 2002). Because turtle populations cannot sustain increased rates of adult mortality (Doroff and Keith 1990; Brooks et al. 1991; Congdon et al. 1993, 1994), this potential source of mortality should be eliminated from the Henry County site. If recommended preserve areas located north of the road are purchased, a corridor should be provided for turtles moving to and from aquatic and terrestrial habitats on each side of the road. The most efficient way to establish a corridor is to install passable culverts under the road, and barriers or guide walls along the sides of the road that would prevent turtles from crossing it. A more elaborate design would include construction of a bridge over the most sensitive area south of Pond 1. Regardless of design, efficacy would be maximized if turtles could see daylight on the other side of the culvert or bridge, and the substrate was composed of natural sand (Aresco 2003).

Optimal preserve design should, in theory, also provide corridors to other mud turtle populations to allow

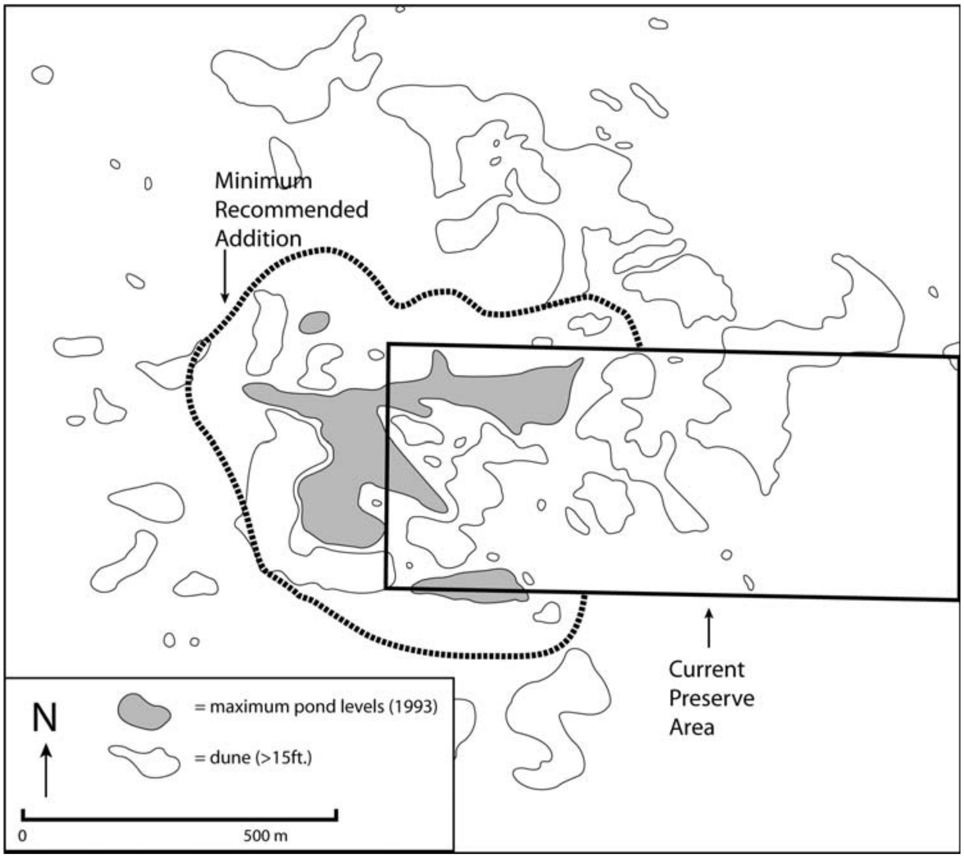

Figure 5. Location of current preserve area and minimum recommended addition area. The minimum recommended addition is terrestrial habitat within 90 m of maximum pond level edges.

for immigration and emigration of individuals. Dispersal routes between populations are necessary for maintaining genetic variability, a condition that is critical for the long-term genetic health of the population. Since the mud turtle population at the Henry County site is a relict, with the closest populations located more than 80 km away across formidable barriers, direct corridors to other populations is not a practical option. A suitable alternative would be the periodic introduction of turtles from large, nearby yellow mud turtle populations. Periodic introductions of individuals from a nearby, genetically similar population to the Henry County site would be the best option for providing long-term genetic variability. Since adult turtles exhibit philopatric behaviors (Iverson 1991; this study), there is a risk that introduced adults would reject their new surroundings; however, introduction of hatchlings should overcome this problem. It is therefore recommended that hatchling yellow mud turtles originating from an appropriately identified population be released at the Henry County site at least every few years to provide genetic variability to the population there.

This study identified high predation rates on mud turtle nests, particularly by coyotes, which located nests by excavating aestivating turtles. A previous study at Big Sand Mound indicated that predator removal led to increased recruitment of hatchling mud turtles. Christiansen and Galloway (1984) reported that, following the removal of raccoons, predation on nests substantially decreased, and greater numbers of hatchlings were observed in ponds following the program. Since high rates of nest predation by mammalian predators were observed at the Henry County site, a predator-removal program is therefore recommended. Predators that should be periodically removed from the site include coyotes in particular, but also raccoons and skunks. Other hatchling predators that could be periodically removed from the site include snapping turtles. Removal of these species on a periodic basis would increase nest success and hatchling survival and would result in the recruitment of greater numbers of individuals into the population. Caution should be taken in undertaking predator-removal programs to enhance recruitment rates because it may take decades for the results of such programs to manifest (see Heppell et al. 1996).

Habitat Management. — Should additional areas be acquired for preserve land, it is recommended that the shortgrass prairie community present in the current preserve area be encouraged to grow in the terrestrial components of any acquired areas. The condition of the terrestrial habitat outside of the area of the preserve is poor to fair, as a thick turf has developed over the dunes through cattle grazing activities. A number of non-native grass species have been introduced into this area to improve the quality of grazing, and the addition of copious amounts of cow dung has encouraged dense growth of these grasses over most of the dunes. Management plans to improve the health of any acquired terrestrial habitat should include techniques to break up the turf and encourage the growth of native bunch grasses and other herbaceous prairie plants. Additional terrestrial habitat management should include controlling the spread of mulberry shrubs and trees around the pond edges because they may represent a barrier to turtle dispersal from ponds to dunes if they are allowed to grow too thick.

The habitat within the ponds in the current study area, despite intense trampling by grazing cattle, appeared healthy. As ponds desiccated in the early and mid-summer 1992, cattle trampled through the ponds when attempting to access drinking water, and totally destroyed all vegetation within the pond basins. Much disturbance was also evident to the soils in the substrate of the ponds, which became pock-marked with hoof-prints. However, dense emergent vegetation returned when heavy rains filled the ponds in late summer 1992 and early spring 1993, and the health of the ponds appeared to rebound completely. Should the pond complex in the current study area be acquired for addition to the preserve, little or no effort will be required to promote healthy aquatic habitat. The mere absence of cattle from the ponds should be sufficient action to promote an optimal aquatic environment.

Direction and Timing of Management Techniques. — Because mud turtles are active in terrestrial habitats between mid-April and late September, and because aestivation burrows and nests are shallow, management activities that involve penetrating the ground surface—including breaking up the turf or constructing a corridor—should occur only during the winter, when turtles are located well below the ground surface in overwintering burrows. Also, because of shallow burrows, nests, and frequent terrestrial movements during the activity period, vehicles should be prohibited from driving over the preserve property. Activities that require ground disturbance, including the operation of vehicles, should occur only between November and March.

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