

1993

Ecology of the State Endangered Yellow Mud Turtle, *Kinosternon flavescens* in Henry Co., Illinois

Michael W. Tuma

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Ecology of the state endangered yellow mud turtle,

Kinosternon flavescens in Henry Co., Illinois.

(TITLE)

BY

Michael W. Tuma

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

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ABSTRACT

Illinois populations of the state endangered yellow mud turtle (*Kinosternon flavescens*) persist in scattered locations on sand prairies. The largest population occurs on a remnant sand prairie of the former Green River Marsh in Henry Co. A study was conducted during 1992 to determine important criteria for preserve design. These criteria included extent of turtle movements within the site and habitat use. Turtles were captured by aquatic hoop traps, drift fence, and by hand from May 11 to August 31. A total of 16 adults, four juveniles, and eight hatchlings were captured. Population size was estimated at 44.80 adults using the Lincoln-Peterson index from recaptures in the drift fence. Radiotelemetry was used to follow the movements of eight adult yellow mud turtles. During aquatic activity periods, radio-tagged mud turtles were located almost exclusively in relatively shallow water (8-40 cm deep) among dense emergent aquatic vegetation. Fecal samples were collected during aquatic activity periods and analyzed. Important food items included insects, plants, snails, and amphibians. Yellow mud turtles left the ponds in late May and early June to aestivate in adjacent sand dunes as the ponds dried. Radio-tagged individuals made aestivation burrows on high sand dunes, typically on east- or south-facing slopes, or on flat areas of dune peaks. Mud turtles relocated to new burrow locations most often during or after periods of rain. Thirty-eight of 41 burrows (93%) were located in areas of sparse prairie vegetation. Nesting was observed for three radio-tagged females while within aestivation burrows from June 21-26. Clutches ranged from four to seven eggs. Two females split their clutch of eggs between two nests, and a

third remained with her nest for seven days after deposition. Important nest predators included coyotes (*Canis latrans*), racoons (*Procyon lotor*), and western hognose snakes (*Heterodon nasicus*). Maximum distances moved by mud turtles from the center of their pond of central activity averaged 311 m, ranging from 190 m to 515 m. Five of eight radio-tagged mud turtles returned to ponds for a second aquatic activity period in July after rains filled the ponds. Turtles that were active for a second period returned to make hibernation burrows on the same dune used for aestivation. Cattle grazing on the site was observed to be detrimental to critical aquatic and terrestrial habitat of the yellow mud turtle. Intense cattle grazing has promoted the growth of sod-forming grasses, and the destruction of aquatic vegetation. Management recommendations include purchasing an area of at least 64 hectares from the landowners, restoring natural prairie conditions to areas degraded by cattle grazing, periodic control of mammalian predators, and periodic sampling of the mud turtle population.

Dedicated in memory of
David Edward Tuma
(1944 - 1976)

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...

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INTRODUCTION

The yellow mud turtle (*Kinosternon flavescens*) is a xerically adapted species generally inhabiting the western plains of the United States and northern Mexico. It was thought to be restricted to this area until Cahn (1931) described a disjunct population inhabiting the Meredosia Bay of the Illinois River in Morgan Co., Illinois. Today other disjunct populations are known from eastern Iowa and northeastern Missouri as well (Fig. 1).

The yellow mud turtle has been protected as an endangered species in Illinois since January, 1978. Special concern for the apparent rarity of this species in the Midwest was voiced as early as the 1930's (Cahn, 1931; Cahn, 1937). Brown and Moll (1979) suggested that just three populations were extant in Illinois and Iowa, and that the population size from this region did not exceed 650. In 1979, an extensive survey of the turtle in Illinois was sponsored by Monsanto Chemical and conducted by E.O. Moll and LGL Ecological Research Associates. This survey and more recent trapping efforts conducted by the Illinois Department of Conservation have recorded turtles from 20 sites in nine Illinois counties (Fig. 1). The only published description of the size of the Illinois population comes from Sweet (1984), who reported that 69 turtles had been marked statewide. Moll (1988) reported that 41 individuals were marked at two adjacent sites in Mason Co. Another population in Henry Co. was sampled in 1979, 1985, and 1991, resulting in a total of 19 marked individuals. Other sites in Illinois have provided only one or a few individual turtles.

The Mason Co. and Henry Co. sites, which are privately owned, are being

considered by the Illinois DOC as potential preserves. In order to determine the size of a preserve needed to maintain a yellow mud turtle population, information was sought concerning the extent of turtle movements and seasonal use of habitat. This paper describes research conducted at the Henry Co. site during 1992.

Objectives of the study included estimating population size, and sex and age structure; determining maximal distances travelled from ponds; and identifying critical habitat, including aestivation and hibernation sites. This information will assist in predicting minimum preserve size and habitat characteristics to be maintained at the site should it be acquired by the state.

HISTORY OF *KINOSTERNON FLAVESCENS* IN ILLINOIS

Systematics - Smith (1951) described the disjunct populations in Illinois as a separate subspecies, the Illinois mud turtle, *K. f. spooneri*. The validity of this subspecific designation, which now includes the disjunct populations from Iowa and northeast Missouri, has been questioned by various authors (Iverson, 1979; Houseal et al., 1982; Berry and Berry, 1984). Iverson (1979) compared *K. flavescens* specimens from populations throughout the range, including the disjunct populations in Illinois, Iowa, and Missouri. Comparing 19 morphological characteristics, he argued support for the subspecies *spooneri*. Houseal et al. (1982) also studied the taxonomy of *K. flavescens*, but did not support the validity of *spooneri* by comparing 18 characteristics. They found *K. f. spooneri* populations to be indistinguishable from *K. f. flavescens* populations from the Nebraska Sandhills. Berry and Berry (1984) concluded that *K. f. spooneri* was synonymous with Nebraskan Sandhills *K. f.*

flavescens in a taxonomic re-analysis comparing 28 mensural and 4 meristic characters. The latter two studies should receive more credibility due to larger sample sizes [245 "*spooneri*" individuals in Houseal et al. (1982) and 130 in Berry and Berry (1984), but only 24 in Iverson (1979)]. Also, the resulting canonical variate dispersion plots from Iverson (1979) show the female "*spooneri*" plot to be directly adjacent to the female *K. f. flavescens* plot, and the male "*spooneri*" plot overlapping with the male *K. f. flavescens* plot.

Collins (1991) has taken a more radical approach by proposing that the disjunct populations be referred to as a completely new species, *Kinosternon spooneri*. He considers these geographically isolated populations as separate lineages and, based on the evolutionary species concept, different species. This view is unacceptable for this particular species, however, because the disjunct populations have only been separated for approximately 4,000 years, not nearly enough time for a new species to evolve.

Furthermore, the phenograms from Houseal et al. (1982) and the dendrographs from Berry and Berry (1984) reveal that the disjunct Illinois, Iowa, and northeastern Missouri populations have not diverged significantly from the Nebraska Sandhills *K. f. flavescens* populations, which in turn have not diverged significantly from *K. f. flavescens* populations to the south and west. Conversely, the disjunct *K. flavescens* populations from north central Mexico, and northeastern Mexico and southern Arizona have diverged, and are worthy of separate subspecies designations (*K. f. durangoense* and *K. f. arizonense*, respectively) [Houseal et al. (1982); Berry and

Berry (1984)]. The population examined in this study will therefor be referred to as the yellow mud turtle, *K. f. flavescens*.

Zoogeography - Smith (1957) formulated a hypothesis describing the zoogeography of this turtle and other western species with similar distributional patterns. The disjunct populations were viewed as relicts of a former wider range which had subsequently undergone a reduction in size. Many of these relict populations are associated with sand prairies which drain well and thus, mimic desert conditions.

During the Xerothermic period which occurred after the most recent glacial retreat (Wisconsinan), western species expanded their ranges eastward along what is called the Prairie Penninsula (Transeau, 1935). This region was characterized by grassland/steppe habitat resulting from increasingly xeric conditions during the period. Zumberg and Potzger (1955) set the maximum age of the Xerothermic at 4,000 ybp, whereas Anderson (1991) placed it between 8,000 and 6,000 ybp. King (1981) described a scenario in which dryer conditions gradually invaded the post-glacial forest/tundra in central Illinois starting at about 13,800 ybp and culminated in a prairie/oak-hickory forest by 8,300 ybp. The Prairie Penninsula originated in the Great Plains and spread as far east as Indiana. In northeastern Kansas, the prairie was well established by 9,900 ybp (Gruger, 1973), and in northwestern Iowa was established between 9075 and 7730 ybp (Van Zant, 1979). The period lasted long enough for western species to move eastward along the penninsula and extend ranges into the Midwest. At the close of the period, a cooler, moister climate returned to

much of eastern North America and many western species requiring dry habitat were eliminated from the East, except in xeric habitats such as sand prairies. Examples of western species surviving in eastern sand prairies other than the yellow mud turtle are Strecker's chorus frog (*Pseudacris streckeri*), the western hognose snake (*Heterodon nasicus*), the ornate box turtle (*Terrapene ornata*), the bullsnake (*Pituophis melanoleucus*), Franklin's ground squirrel (*Spermophilus franklini*), the pocket gopher (*Geomys bursarius*), and the prickly pear cactus (*Opuntia* spp).

The presence of *K. flavescens*, *Terrapene ornata*, and *Heterodon nasicus* in the sand prairies of Henry Co. supports Smith's 1957 zoogeographic hypothesis concerning the Prairie Peninsula of the Xerothermic Period. All of these species show affinities to eastern sand prairies, and relationships with western populations.

Studies concerning the origin of western species occurring in Illinois as a result of the Xerothermic period show that *K. flavescens* dispersed from an area comparatively much further to the north than did other species. Moll (1962) compared blotch patterns of *H. nasicus* in northwest Illinois with western populations and concluded that the Illinois populations were representative of a former intergrade zone of two subspecies, *gloydi* and *nasicus*. They correspond to those of populations in the Great Plains at the northern limits of the area of intergradation of the two subspecies in central Oklahoma.

Disjunct Illinois populations of the central lined snake (*Tropidoclonion lineatum*) appear to have originated from populations further north than did the *H. nasicus* populations. Smith and Smith (1963) showed that certain disjunct populations

in northcentral Illinois, and northwest Illinois and western Iowa are most similar to populations in the subspecies intergrade zone that occurs in Kansas.

Houseal et al. (1982) and Berry and Berry (1984) reported that disjunct *K. flavescens* populations in Illinois, Iowa, and northeastern Missouri are most closely related to disjunct populations in the Nebraska Sandhills. A dispersal corridor out of Nebraska was likely the Middle Western Upland Plain connecting the Nebraska Sandhills with eastern Iowa and western Illinois (Hammond, 1970). The topography of these plains supports *playas*, the primary aquatic component of mud turtle habitat. Playas, which are common throughout the western plain states, are shallow ponds that form in depressions during spring rains and usually become dry by mid-summer. The Middle Western Upland Plains were also likely traversed more quickly than more southerly corridors, which include barriers in the form of the West-Central Rolling Hills and the Ozark-Ouachita Highlands (Hammond, 1970). A disjunct population of yellow mud turtles occurring in southwest Missouri is likely a relict of the Xerothermic period, and is related to populations from the Arkansas River in southcentral Kansas (Houseal et al., 1982) from which dispersal probably originated. This dispersal route was not as extensive as the route from Nebraska as it was likely slowed by the topography of the region. Given the short time frame of the Xerothermic period, the northern route from the Nebraska Sandhills was the only one that could allow invasion into Illinois before the close of the period and disappearance of the dispersal corridors. The dispersal of *H. nasicus* and *T. lineatum* were likely less affected by the topography, allowing invasion by populations further to the south.

STUDY SITE

The study site (Figs. 2 & 3) is located in the northeast corner of Henry Co., about 5 km north of Annawan on properties owned by Bill Frankenreider and Mark Guthrie. The area proposed for acquisition as a preserve includes 32 hectares owned by Frankenreider and an adjacent 32 hectares owned by Guthrie. Both properties are used for grazing cattle. The site is characterized by low-lying areas supporting eight temporary ponds (or playas), surrounded by rolling sand dunes.

The soil of the low marsh areas is heavy Orio and is rich in organic material which stains the water in the ponds. Most of the soil surrounding the Orio is Oakville loamy fine sand. The ponds are shallow when full, ranging from 20 to 120 cm maximum depth.

During 1992, the larger ponds were full in early May when the study began but dried completely by the end of the second week in June. They remained dry until heavy rains filled them during the first and second weeks of July. Aquatic vegetation was relatively sparse in May but was extensive in July and August. The emergent aquatic vegetation was dominated by water smartweed (*Polygonum amphibium*), water pepper (*P. hydropiperoides*), sedge (*Carex comosa*), and spikerush (*Eleocharis obtusa*). Duckweed (*Lemna* sp.) was present but was relatively sparse compared to nearby ditches where it was extremely abundant.

The terrestrial vegetation is best described as shortgrass prairie and oak/cottonwood savannah. The prairie is dominated by little bluestem (*Schizachyrium scoparium*). The dune area to the east of the pond complex is savannah typified by

open woodlands dominated by white oak (*Quercus alba*) and eastern cottonwood (*Populus deltoides*). A large population of the state endangered broomrape (*Orobanche ludoviciana*) occurs at the site, as does Hill's thistle (*Cirsium pumilum*), a species under consideration for Federal protection.

Species of amphibians and reptiles inhabiting the site other than the yellow mud turtle include the tiger salamander (*Ambystoma tigrinum*), the American toad (*Bufo americanus*), the cricket frog (*Acris crepitans*), the gray treefrog (*Hyla versicolor*), the western chorus frog (*Pseudacris triseriata*), the bullfrog (*Rana catesbeiana*), the green frog (*R. clamitans*), the northern leopard frog (*R. pipiens*), the snapping turtle (*Chelydra serpentina*), the painted turtle (*Chrysemys picta*), Blanding's turtle (*Emydoidea blandingii*), the ornate box turtle (*Terrapene ornata*), the prairie lined racerunner (*Cnemidophorus sexlineatus*), the western fox snake (*Elaphe vulpina*), and the western hognose snake (*Heterodon nasicus*).

The site is located in part of what was historically the extensive Green River Lowlands. The geology of the area is quite complex primarily because of glacial influences. The following account is based on an interpretation by Follmer et al. (1986).

It is believed that the Wisconsin glacial advance (180,000 - 10,000 ybp) had major effects on the drainage patterns in this area. During this time the Mississippi River flowed in channels to the east of its present channel, in between the loess hills west of Rock Falls, Illinois to the "big bend" of the present Illinois River channel near Hennepin, Illinois. The Woodfordian advance blocked the southerly flow of

water from the lowlands causing a large lake to form, and a considerable amount of sand was deposited. Eventually the impoundment was breached and water flowed through a new channel to the west where the present Mississippi River channel exists. During the late Woodfordian large sand dunes as high as 20 m were formed in the lowland.

In post-glacial and historic times the Green River spread over a broad area in the lowlands. This 200 million hectare wetland was historically known as the Green River Marsh. Extensive shallow marshes persisted through early summer but usually dried by late summer, except during wet years. During exceptionally dry years, fires were common in the fall which maintained the prairie vegetation. In 1901 the marsh was drained for agricultural purposes and the Green River was channelized. The study site with its temporary ponds and sand hills is likely a remnant of these marshes and Woodfordian dunes. It is located about 8 km south of the current Green River channel.

METHODS

Turtles were captured by baited hoop traps, drift fence, and by hand. Hoop traps baited with chicken livers were placed in ponds deep enough to accommodate them (> 30 cm). Trapping occurred from May 11 to June 12 and again from July 16 to August 17. Relative abundances of each species of aquatic turtle was determined by comparing numbers of turtles captured by hoop trap per trap hour (exclusive of recaptures). A 75 m section of drift fence was constructed on May 12 and positioned along the border of the Frankenreider/Guthrie tracts in between pond

#8 and the sand dunes to the east (Fig. 3). The fence was constructed directly beneath the electric fence separating the two properties so that it would not be trampled by cattle. Each turtle captured was marked by notching marginal carapace scutes (Cagle, 1939). Data recorded for each turtle included species, sex, carapace length (CL), carapace width (CW), plastron length (PL), weight (W), and height (H), as well as any distinguishing features. Age was estimated by counting growth rings on the right post humeral scute, and a stencil rubbing was made for the entire plastron. During the egg-laying season, females were palpated for eggs.

Radiotelemetry

Radiotelemetry was used to follow the movements of nine adult yellow mud turtles, one adult painted turtle, one adult Blanding's turtle, one adult ornate box turtle, and one juvenile snapping turtle. Radiotransmitters encased in dental acrylic were glued to the carapace using additional dental acrylic. Turtles were released at the point of capture after being fixed with a radio, usually within 24 h. Movements were monitored daily from date of capture to August 12, and weekly from August 12 to October 10. Location, distance moved since last tracking, behavior, and habitat utilized were recorded. Locations were plotted on a topographic map of the study site.

Translocation Experiment

Translocation of yellow mud turtles from a large population to a dwindling one may be one method of conservation. One adult yellow mud turtle was translocated to a pond 350 m away within the study site and its movements were tracked using

radiotelemetry.

Diet Analysis

Fecal samples were collected from radio-tagged turtles as they were located during aquatic activity. Samples from *K. flavescens* were easily taken by alternately pressing the anterior and posterior lobes of the plastron. Samples from other species were taken by retaining the turtle in a container until it defecated. Fecal samples were preserved in a 10% formalin solution.

Identifiable contents of the samples were separated according to food type (insects, snails, vertebrates, and plants) and dried under a fume hood. Dry weights of each food type were recorded and diet was expressed as the ratio of dry weight of each food type to dry weight of the total identifiable remains.

The ratio of occurrence of each food type in each of the fecal samples was also calculated. This analysis would not show bias because of differences in digestibility that likely resulted from the dry weight analysis. Soft, easily digested foods (e.g., amphibians) are likely greatly underestimated in dry weight analysis of fecal samples.

Environmental Conditions

Soil and vegetation conditions were compared between the Frankenreider and Guthrie tracts to determine the effects of intense cattle grazing on the Frankenreider tract. Three 100 m transects were sampled from each tract *a posteriori* to the habitat preference analysis determined by radiotelemetry. Transects were located on areas that were potentially favorable to mud turtles for aestivation and hibernation burrows

and nest sites (i.e., on south-facing or east-facing slopes of high dunes). Five randomly placed 1 m x 1 m plots per transect were visually analyzed for percent of estimated vegetative cover. A 300 g soil sample was taken at the center of the plot, to a depth of approximately 10 cm. Dry weight of the sample was recorded, and the contents of the sample were spread across a sieve with openings small enough to trap sand particles. Smaller particles were washed through the sieve with a spray of water. The washed sand sample was then air-dried and dry weight was recorded and expressed as percent sand per sample.

Weather conditions, including precipitation and minimum and maximum daily temperatures were taken from the nearby Illinois State Water Survey weather station in Galva. Local conditions at the site were also recorded including air, water, and soil temperatures, cloud cover and precipitation. During aestivation and hibernation periods, burrow temperatures were recorded as the temperature of the sand directly beneath the plastron of the mud turtle.

Population Estimate

Population size was estimated using the Lincoln-Peterson index based on recaptures in the drift fence. The first capture period occurred as turtles left the ponds for summer aestivation, and the second period occurred as they left aestivation and returned to the ponds. However, since not all turtles re-entered the ponds for a second activity period after aestivation, the population estimate was adjusted in order to account for the turtles that remained inactive, thereby avoiding capture in the drift fence. The radio-tagged turtles were assumed to represent a random sample, and the

proportion of these that remained inactive was assumed to be the proportion of the entire population that remained inactive.

The drift fence was effective in capturing turtles that migrated to and from dunes on the Guthrie tract. The mud turtles captured in aquatic hoop traps and radio-tagged prior to summer aestivation were assumed to be a random sample, and the proportion of these that utilized dunes on the Guthrie tract was assumed to be the proportion of the total population that utilized these dunes as well. The estimate was therefor adjusted to include the turtles that utilized other dunes.

RESULTS

Turtles captured at the site were snapping turtles (*Chelydra serpentina*) (n = 7), yellow mud turtles (*Kinosternon flavescens*) (n = 26), painted turtles (*Chrysemys picta*) (n = 15), Blanding's turtle (*Emydoidea blandingii*) (n = 1), and ornate box turtles (*Terrapene ornata*) (n = 1) (Table 1). Three turtles were recaptures from trapping efforts in previous years. *Emydoidea blandingii* (L3L9) was originally captured and marked in May of 1991, *K. flavescens* (L1R2) was first captured in 1985, and *K. flavescens* (L8) was a recapture from the 1979 trapping survey.

In 12,528 trap hours using baited hoop traps, turtles were captured at the following rates (turtles/trap hour): *C. picta* - 1.04×10^{-3} ; *K. flavescens* - $.559 \times 10^{-3}$; *C. serpentina* - $.479 \times 10^{-3}$; *E. blandingii* - $.08 \times 10^{-3}$. It would appear that *C. picta* is the most abundant species, with a relative abundance of approximately twice that of *K. flavescens* and *C. serpentina*. The Blanding's turtle captured was probably the only one at the site.

All aquatic turtle species were captured by hoop traps in May but only *K. flavescens* was captured in the drift fence. Several mud turtles were also captured by hand as they migrated to and from the dunes for aestivation and hibernation. Adult mud turtles were captured by drift fence during three periods: 1) as they left the ponds for aestivation, 2) as they returned to the ponds after aestivation, and 3) as they left the ponds for hibernation (Fig. 4).

Seven *K. flavescens* hatchlings were captured by drift fence between May 12 to June 30. An additional hatchling was hand captured in a blowout area of a dune on June 14. It was 150 m away from the closest pond, which at the time was dry. These individuals were apparently emerging from nests in which they overwintered. Late emergence of hatchlings has previously been reported by Christiansen and Gallaway (1984).

Radiotelemetry

Three radio-tagged turtles were lost because of radiotransmitter failure (*T. ornata* L1, *C. serpentina* L3 and *K. flavescens* L8R2). Two others were lost after they dispersed from the drying ponds (*C. picta* L2R2 and *E. blandingii* L3L9). The remaining eight *K. flavescens* were tracked through the summer and into the winter months (Table 1).

Home Ranges - All radio-tagged *K. flavescens* had actual home ranges which included terrestrial aestivation and hibernation sites in sand dunes (Figs. 5-12). Home ranges outside of the ponds were essentially linear as the turtles moved to and from the dunes. Four of the six adults captured in hoop traps previous to summer

aestivation entered sand dunes to the east of pond #8. Two additional adult females (L9R8 & L9R9) were captured in the drift fence as they moved toward the same dunes, and were radio-tagged. All six of the radio-tagged turtles that aestivated in these dunes inhabited ponds #7 & #8 during either pre-aestivation aquatic activity or post-aestivation aquatic activity, or both (Figs. 6-9, 11, & 12). One female (L9R8) also inhabited pond #9 during a third aquatic activity period (Fig. 12). Another (L3R3) inhabited pond #7 in May but aestivated in sand dunes to the north and west of the pond (Fig. 10).

A male (L1L2) that originally inhabited pond #5 aestivated in the dune to the north. He emerged from aestivation on July 19 and moved to pond #1. He was released at pond #8 for a translocation experiment, and remained there until July 26, when he moved to pond #5. He stayed in this general area, inhabiting ponds #4, #5, and #6 until August 23, when he returned to hibernate only 20 m to the south of his original aestivation site (Fig. 5).

Other radio-tagged mud turtles that entered a second aquatic activity period (L9R8, L9R9, L1L2L3, and L1R2) also returned to the same slope of the same dune for hibernation that they used for aestivation. Hibernation sites were remarkably close, within 2 to 5 m of the original aestivation sites.

Maximal distances moved from the ponds by the radio-tagged turtles were calculated as maximal distance moved from the center of the pond of central activity for individual turtles. Maximal distances moved by mud turtles ranged from 190 m to 515 m from pond of central activity (\bar{x} = 311 m, s = 105.5, n = 8) (Table 2).

Maximal distances moved by other radio-tagged aquatic turtles from pond of central activity were more extensive. The Blanding's turtle (L3L9) was located in a drainage ditch as far as 4.7 km from his pond of central activity before his radio failed, and the painted turtle (L2R2) was located in the same drainage ditch 1.2 km away from his pond of central activity before his radio failed.

Figure 13 shows a composite home range for all radio-tagged mud turtles as determined by a circle encompassing the maximal location points for each turtle.

Seasonal Activity - All species were active in the ponds when the study began on May 11. *Kinosternon flavescens* was the only species that remained on the site when the ponds dried during June. Two radio-tagged turtles (*E. blandingii* L3L9 and *C. picta* L2R2) dispersed to a drainage ditch 1200 m to the south of the site. Snapping turtles were the last to remain in the drying ponds, but many tracks were observed leaving the area when the last of the water disappeared. *Kinosternon flavescens* was the first species to reinvade the ponds when they filled in July. *Chelydra serpentina* specimens were also captured in the ponds in July and August, but the radio-tagged *C. picta* and *E. blandingii* did not return.

While inhabiting the ponds, yellow mud turtles were observed foraging actively from sunrise to twilight. It is unknown whether they foraged at night, but considerable movement by the turtles was evident.

The six radio-tagged adult *K. flavescens* (L1L2, L1L2L3, L1R2, L2R2, L3R3, and L9) captured by hoop traps in May had all begun aestivation by June 3.

Movement to the dunes for aestivation occurred mainly in the early evening. On May

27, five individuals exited pond #8 between 5:30 and 7:00 pm. During aestivation, most individuals remained within relatively shallow burrows (5-25 cm depth) where mid-day maximum temperatures ranged from 19 to 30 C (\bar{x} = 24.3 C).

Aestivation was not necessarily a period of inactivity. Turtles frequently moved to new burrow sites and movement within the 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. When such a burrow was approached, the turtle would quickly withdraw its head. This behavior, as well as movement to new burrow sites, occurred most often during overcast or rainy conditions. For 26 observations of movement to new burrow sites during aestivation, 18 occurred during overcast or rainy conditions. A chi-square analysis revealed that movements to new burrow sites were significantly more likely during these conditions ($\chi^2 = 3.846$, $p = 0.05$, $df = 1$). Seven of the 8 movements that occurred during clear weather were by females prior to egg deposition. Seven "peekholes" were observed, all after rain.

Females relocated to new burrow sites during aestivation ($\bar{x} = 6.33$, $s = 2.9$, $n = 3$) significantly more frequently than males ($\bar{x} = 2.4$, $s = 2.3$, $n = 5$) ($t = 0.05$, $df = 6$). Twenty-two of the 24 (92%) relocations to new burrow sites by females occurred before egg deposition. Distances moved between burrow sites for all turtles ranged from 1.5 m to 225 m ($\bar{x} = 36.5$ m, $s = 48.9$ m, $n = 35$). However, during the one week period before and during egg deposition, distances moved to new burrow sites by females were relatively shorter (1.5 to 29 m, $\bar{x} = 12.8$ m, $s = 9.22$, $n = 16$).

A summary of seasonal activity for all radio-tagged mud turtles is shown in Figure 14. Five of eight radio-tagged *K. flavescens* (L9R8, L1L2L3, L1L2, L9R9, and L1R2) entered the ponds for a second aquatic activity period between July 8 and August 30. L9R8 emerged for a third aquatic activity period in pond #9 between September 10 and 25. One male did not enter the ponds for a second activity period (L2R2) and overwintered in the same burrow used for aestivation. Two other mud turtles that did not return to the ponds for a second aquatic activity period (L3R3 and L9) moved to new burrow sites in August following heavy rainfall.

The turtles maintained relatively shallow burrows until October when they began to dig deeper. Five turtles were unearthed during fall and winter months to change their radiotransmitters. In early October mean burrow depth was 64 cm (n = 2). During late October through December mean burrow depth was 116.67 cm (n = 3).

Utilization of Aquatic Habitat - Radio-tagged *K. flavescens* specimens were almost always found associated with emergent vegetation in relatively shallow water (8-40 cm deep). In July and August when aquatic vegetation was at its peak, they were located foraging along weed-choked shallow pond edges exclusively.

Soft muddy pond substrate also appeared to be an important habitat component. Most individuals burrowed into the mud one to four days prior to leaving the ponds for aestivation. Some individuals burrowed into the pond substrate on cool, overcast days as well.

Utilization of Terrestrial Habitat - High sand dunes were utilized for

aestivating and overwintering sites. The turtles seemed to orient toward the highest point of a dune when exiting ponds suggesting that visual orientation may be important in finding the site. One individual (L1L2L3) was observed peering out of the water for several minutes on the day he exited pond #8 for aestivation.

Turtles burrowed into sand dunes with open sparse prairie vegetation in 38 of 41 (93%) observations. In three instances, burrows were made through thick grass sod, but the turtles had less success burrowing in these areas. In two instances, turtles retreated under small shrubs, but only for a few hours each time. Generally, areas near shrubs or trees were avoided. Fourteen burrow locations were located in flat areas, either on top of a dune or in a flat between dune peaks. Seventeen locations were on east-facing slopes and nine occurred on south-facing slopes. Only one occurred on a west-facing slope and none occurred on north-facing slopes. A chi-square goodness of fit test applied to the occurrence of burrows on zero slope, north-, south-, east-, and west-facing slopes showed that the observed distribution of burrows on flats, east-facing and south-facing slopes is significantly different from the expected distribution of equal occurrence ($\chi^2 = 28.138$, $p < 0.01$, $df = 4$).

Diet Analysis

A total of 17 fecal samples were collected from six *K. flavescens* ($n = 12$), three *C. serpentina* ($n = 4$), and one *C. picta* ($n = 1$). Contents of the samples were separated according to food type present: Plant material, snail remains, insect remains, and vertebrate remains. A significant amount of unidentifiable material was also present, probably the soft tissues from insects, snails, and amphibians. A

summary of the proportions of dry weights of each identifiable category is presented for each sample in Table 3.

Based on the average of the samples from all mud turtles, *K. flavescens* fed mainly on insects (57%), followed by plant material (31%), *Helisoma* snails (12%), and amphibians (<1%) (Figure 15). The occurrence of each food type in the twelve mud turtle fecal samples were as follows: All twelve samples contained insects and plants, six samples (50%) contained snails, and three samples (25%) contained small anuran bones, which were likely from *Acris crepitans* (Fig. 16). Two direct observations of feeding were made in the field: One radio-tagged *K. flavescens* was observed pursuing a *Rana clamitans* tadpole on May 28, and another radio-tagged mud turtle was observed pursuing a Hydrophilid beetle on August 4.

Snail remains were present only in samples collected from *K. flavescens*. A sample collected from a prenesting female in May had an unusually high proportion of *Helisoma* remains.

Plants and arthropods were important food sources for all turtle species, as remains of both were present in all fecal samples collected. Arthropods were especially important for *C. serpentina*, averaging over 82% for the samples collected.

Reproduction and Predation on Nests and Hatchlings

Nests of four *K. flavescens* females were observed in the sand dune areas surrounding the ponds between June 22 and June 26. Three of the nesting individuals were radio-tagged specimens. The first nest discovered was from an untagged specimen on June 22, and contained three eggs. It was located at the top of the sand

dune 110 m to the southeast of pond #8. Another nest containing two eggs was found on June 22 when a burrow previously occupied by L3R3 was checked. After laying the eggs, she had moved to a new burrow 3 m to the northwest sometime between 3:00 pm on June 21 and 3:30 pm on June 22. On June 23 the new burrow position was checked and a *Heterodon nasicus* was found preying on two more eggs that had been deposited. The turtle had moved a considerable distance (225 m) to the west after laying these last two eggs. Both nests were within 65 m of pond #7.

On June 25 L9R9's burrow was checked and the remains of 2-4 eggs were found unearthed and destroyed. She was located 3 m to the southwest in another burrow. When this burrow was checked on June 26, the remains of two more eggs were found unearthed and destroyed. She was found unharmed 1.5 m to the north in still another burrow. Both nests occurred within 125 m to the east of pond #8.

Also on June 26, L9R8 was found within her burrow on top of a clutch of seven eggs. The nest was 200 m to the southeast of pond #8. She remained in this burrow on top of her clutch of eggs until July 6, when she moved back to pond #8.

Intact nests ranged from 10-20 cm ($\bar{x} = 12.6$ cm, $s = 5.4$ cm, $n = 4$) deep and occurred in open areas of sparse prairie vegetation. Nests were located on slopes ranging from 0 to 50 degrees, and four of the six occurred on an east-facing slope. Eggs averaged 29.2 mm in length ($n = 11$, $s = 0.91$) and 16.9 mm in diameter ($n = 11$, $s = 0.70$).

All observed nests were destroyed by predators by the end of the summer. The nests of the untagged female and L9R9 were most likely destroyed by coyotes

(*Canis latrans*). Several coyote den entrances were observed on the sand dune to the southeast of pond #8. Tracks found around the destroyed nests matched those found around the den entrances. Two adult mud turtles aestivating on this dune were unearthed by coyotes during the nesting season in an apparent attempt to find nests. It is possible that the coyotes were attracted to the scent of the turtles rather than the scent of the eggs as one of the adult turtles unearthed was a male.

The first nest left by L3R3 was destroyed by a raccoon (*Procyon lotor*), as evidenced by tracks. L9R8's nest, which was protected by a hardware cloth cage, was destroyed by small mammals that burrowed underneath the cage.

Remains of a mud turtle hatchling were found in a fecal sample of a *Chelydra serpentina*, and a *Heterodon nasicus* captured near the drift fence was palpated and found to contain an object believed to be a hatchling mud turtle.

Population Estimate

Four of the six adults captured by hoop traps prior to summer aestivation utilized dunes on the Guthrie tract. Therefore, an estimate of numbers of turtles derived from recapture data from the drift fence should represent two thirds the estimated size of the entire population.

A total of 12 adult mud turtles were captured in the drift fence, seven before aestivation and eight after aestivation, three being recaptures:

$$\frac{3 (r)}{8 (n)} = \frac{7 (M)}{N} \text{ or } N = 18.67$$

Five of eight radio-tagged mud turtles emerged for a second activity period in

the ponds. Assuming that this ratio is a random representation of the entire population, then the number of turtles caught in the second sample represents only 5/8 of the total that would have been caught if all the turtles emerged for a second activity period. The sample side of the equation should be adjusted by 5/8 to include those that remained inactive:

$$\frac{3 (r)}{8 (n)} \times \frac{5}{8} = \frac{15 \text{ (adjusted r)}}{64 \text{ (adjusted n)}} = \frac{7 (M)}{N} \quad \text{or} \quad N = 29.87$$

Total numbers of adults utilizing the Guthrie dunes is estimated to be 29.87 with a 95% confidence interval of ± 16.7 . Assuming this figure represents two thirds of the entire adult population, then the estimated population size is 44.80 adults. Using the same variance, it is 95% probable that the population size is between 28 and 62 mud turtles (over the age of one year).

Environmental Conditions

Soil and Vegetation - Three transects for the vegetation and soil analyses occurred on east-facing slopes and three occurred on south-facing slopes. Three of these transects also partially overlapped with flat areas. Mean estimated vegetative cover was significantly greater for plots on the Frankenreider tract (transects 1-3: $\bar{x} = 76.67\%$, $s = 15.22$, $n = 15$), than plots on the Guthrie tract (transects 4-6: $\bar{x} = 27.67\%$, $s = 16.52$, $n = 15$). Sod-forming grasses (especially *Poa pratensis* and *Agrostis alba*) were extremely abundant on the Frankenreider tract, whereas bunch-forming grasses (*Schizachyrium scoparium*, *Sporobolus cryptandrus*, *Stipa spartea*, and *Koeleria cristata*) dominated the Guthrie tract.

Soil samples from plots on the Guthrie tract contained significantly more sand ($\bar{x} = 99.33\%$, $s = 0.94$, $n = 15$) than plots on the Frankenreider tract ($\bar{x} = 90.33\%$, $s = 2.49$, $n = 15$). The color of the soil on the Frankenreider dunes also appeared much darker, primarily as a result of accumulation of cattle feces.

Weather - Drought conditions prevailed during May and June. The weather station at Galva recorded only 0.47 inches during May (a record low) and 2.02 inches in June. By contrast, averages for the previous 31 years were 3.91 inches for May and 4.18 inches for June. As a result of the drought, the ponds were completely dry by June 12. Precipitation in July was recorded at 12.50 inches (a record high) and the ponds were filled to levels higher than had previously been observed in the spring. This promoted rapid growth of aquatic macrophytes in the ponds. Also, ponds #7 & #8, and ponds #5 and #6 were adjoined by extensive shallow marsh areas.

DISCUSSION

Comparative Aquatic Turtle Adaptations - *Kinosternon flavescens* appeared to be better adapted to conditions at the site during 1992 than other aquatic turtle species. Their highly terrestrial behavior allowed them to escape adverse conditions that forced the more aquatic species to undertake extensive overland migrations in search of other water sources. These harsh conditions included drought in the summer and complete freezing of ponds in winter.

The mud turtles responded to drought conditions much differently than any other aquatic turtle species at the site. By aestivating, they avoided the need to

disperse to new bodies of water to continue their aquatic activity. Aestivation may be a behavior that evolved in arid environments where it was not feasible to disperse to distant permanent bodies of water during periodic water shortages. Yellow mud turtles inhabiting permanent water in New Mexico do not aestivate (Christiansen and Dunham, 1972), but populations in Oklahoma (Mahmoud, 1969), and Iowa (Christiansen et al., 1985) aestivate regardless of the presence of permanent water. Mud turtles in this study exited the ponds before they were dry, suggesting that aestivation is a common behavioral characteristic of this species. Long (1986) 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.

Reproductive success of the highly aquatic turtles is likely negatively affected by drought. Gibbons et al. (1983) reported a decrease in nesting of various aquatic turtle species following a major drought in South Carolina. The only species whose reproduction was not affected was *Kinosternon subrubrum*, an aquatic species which, like *K. flavescens*, is highly terrestrial. Reproductive attempts of *K. flavescens* appeared unaffected by drought because this was the only species observed nesting. Hatchlings were observed for both *K. flavescens* and *C. picta*, but the mud turtle hatchlings appeared to be better adapted for drought conditions. One mud turtle hatchling was observed burrowing into a sand drift when the ponds were dry. Others probably burrowed into mud in the pond beds as they dried. The only painted turtle hatchling observed was in a small puddle in the nearly dry pond #7. Its chances for

survival appeared slim as its only alternative after the pond dried was to disperse to a drainage ditch 1200 m away.

Kinosternon flavescens is probably the only turtle species able to hibernate at the site as adults. Terrestrial hibernation allows them to escape the danger of freezing in the shallow ponds which were observed to be completely frozen during winter, rendering them unsuitable as hibernacula. Radio-tagged mud turtles were located hibernating well below the frost line in the dunes. Christiansen and Bickham (1989) reported an increase in relative abundance of yellow mud turtles at Big Sand Mound in Iowa after severe winter conditions killed other turtles hibernating aquatically.

The mud turtles appear to be philopatric, returning to the same area to aestivate and hibernate. Radio-tagged individuals that entered a second aquatic activity period returned to hibernate in the same dune where they aestivated. Even the translocated male (L1L2) was able to relocate its original dune, suggesting that the turtles are able to recognize features in their home range. Possibly, individuals may imprint to and use the dune from which they emerged as hatchlings, returning to it year after year to aestivate, nest and hibernate. Future studies should explore this possibility.

It would appear, then, that the Henry Co. *K. flavescens* population is very site specific in a long-term sense, whereas other aquatic turtle species drift through in waves of dispersal from year to year as the ponds dry and rehydrate. The temporal nature of the ponds along with complete freezing may inhibit permanent residence by highly aquatic turtles. The home ranges of the Henry Co. mud turtles are relatively

small, and are confined to ponds and the dunes directly adjacent to them. Home ranges of other radio-tagged aquatic turtles at the site proved to be more extensive as a result of their migrations in search of aquatic habitat.

Nesting Behavior - Females changed burrow locations more frequently than males possibly to locate favorable nest sites. Shorter distances travelled to new burrow sites during this period probably reduce risk of predation.

Two females (L3R3 and L9R9) divided their clutch of eggs between two nests. Multiple nesting has been previously documented for very few turtle species. Moll (1980a) reported this behavior for the Malaysian river terrapin, *Batagur baska*. Fitch and Plummer (1975) attributed the discrepancy between small nest compliments and large oviductal compliments of eggs in smooth softshell turtles (*Apalone mutica*) to multiple nesting. Similarly, Iverson et al. (1991) suggested that *Kinosternon hirtipes* females divide clutches between two nests to explain why the numbers of eggs found in nests are smaller than the full ovarian compliments. This strategy may increase nest survivorship by spreading the risk of total clutch failure to predation.

Another unusual nesting strategy that has evolved in turtles is remaining with the nest for an extended period of time after oviposition. Iverson (1990) reported this behavior for yellow mud turtles in the Nebraska Sandhills and suggested that it may be a form of parental care. The only other chelonian reported to remain with the nest for an extended period after deposition is *Geochelone emys*, the Burmese brown tortoise (McKeown et al., 1982).

Iverson hypothesized that the behavior deterred predation by *Heterodon*

nasicus, the principle nest predator in the Sandhills. Nest predation in this study, however, was primarily by mammalian predators (coyotes and racoons). At Big Sand Mound, Iowa, racoons are the principal predators (Christiansen and Gallaway, 1984). Such predators are likely not deterred by the mere presence of an adult turtle, and in the case of the coyotes, the presence of the female may even attract the predator to the nest. These predators have apparently learned that mud turtles often will be buried with a nest of eggs. Remaining with the nest may be a relict parental care behavior which evolved in the desert southwest where reptilian predators are more common. However in the East, this behavior may actually result in higher predation rates by the more common mammalian predators.

Diet - Adult yellow mud turtles preyed a variety of food items, and appeared to be important top carnivores in the trophic structure of the aquatic community at the site. Comparison with other studies concerning the diet of the species suggests that *K. flavescens* is widely opportunistic in its feeding habits.

Insects, snails, and plants are common dietary complements (Christiansen et al., 1985; Kofron and Schreiber, 1985; Moll, 1988), although Kofron and Schreiber (1985) regarded plant material in fecal samples as incidentally ingested items.

Crayfish (Decapoda) are taken when available (Kofron and Schreiber, 1985).

Vertebrates are also important dietary complements. In fishless aquatic habitat, tadpoles are important (Moll, 1988) whereas fish are taken when available (Christiansen et al., 1985; Kofron and Schreiber, 1985). Although tadpole remains could not be identified in the fecal samples examined in this study, they are believed

to be very important food items.

Population Estimate - The population size of *K. flavescens* in Henry Co. is fairly small, and likely on the verge of extinction. Nonetheless, the turtles are reproductively active, with what appears to be meager recruitment.

Data from the 1992 season yielded an estimate of 45 adults, with a 95% confidence interval ranging from 28 to 62 adults. As of May 1993, 45 mud turtles over the age of one year have been marked at the Henry Co. site, making this the largest population in the state. Thirty-one of these individuals have been observed since 1991. Nesting was observed and juveniles and hatchlings were captured during the 1992 season. The age distribution of the population during 1992-93 includes 12% juveniles between the age of one and two years and 17% juveniles under one year of age, indicating some recruitment. It is unknown if this recruitment rate is high enough to offset the mortality rate. However, with careful management, this population has the potential to recover.

Management Considerations - The original marsh and sand prairie habitat of the site has been greatly altered as a result of the cattle grazing. The resulting problems are more pronounced on the Frankenreider tract, and comparisons with the Guthrie tract should aid in making management recommendations.

It is possible that the majority of mud turtles utilize dunes on the Guthrie tract because they have been more successful in the more pristine conditions. There are fewer cattle and a larger area to graze on the Guthrie tract, and the negative effects on the habitat have been less severe compared to the Frankenreider tract which has

both larger numbers of cattle and a smaller area to graze.

Vegetation on the Frankenreider tract resembles a mowed golf course, and is covered by a thick layer of sod-forming grasses. The constant grazing of the cattle has kept the vegetation trimmed to the ground. Most native prairie plant populations have declined or have been eliminated due to the intense grazing pressure and from competition with non-native fast-growing grasses introduced to the area.

Soil and vegetation conditions on the Guthrie tract are more natural. The native prairie plant community is much more diverse and plants are not stunted or eliminated by grazing pressure. The sand dunes are not covered with cattle feces, and vegetation is relatively sparse. These conditions no doubt make burrowing and nesting easier for the turtles.

Hatchling mud turtles are probably especially sensitive to burrowing conditions, particularly when emerging from nests in spring and summer. Possibly some could not dig through the thick sod on the Frankenreider tract and died. Also likely is the possibility that females avoid such areas of thick sod and seek other dunes to deposit eggs, explaining why the Guthrie tract is utilized by more turtles.

If conditions on the Frankenreider tract are in fact limiting the success of the turtles utilizing those dunes, and the turtles are indeed philopatric to a specific dune, then it should be expected that ultimately, mud turtles will be eliminated from the dunes on this tract should conditions remain the same. Should the land be acquired for a preserve, an effort should be made to restore dune conditions similar to those on the Guthrie tract. This would probably involve breaking the thick sod and replanting

the area with native prairie vegetation.

Another detrimental effect produced by the cattle is destruction of aquatic vegetation. Cattle frequently visit the ponds *en masse* to cool themselves, drink, and forage. In doing so, they trample or eat most of the vegetation in the water. Since emergent aquatic vegetation provides important habitat for the mud turtles, their foraging success would likely be enhanced by removal of cattle from the site. Dense emergent vegetation may also provide a critical retreat-site and foraging habitat for hatchling mud turtles. Donald Kangas (pers. comm.) observed several hatchling yellow mud turtles in shallow water with dense aquatic macrophytes in Clark Co., Missouri.

Several stands of small trees and shrubs have grown around the periphery of ponds #7 and #8. They are not natural prairie vegetation, and persist mainly because they are thorny and are not eaten by the cattle. As *K. flavescens* may be locating dunes and ponds by vision, the presence of the shrubs and trees may hinder the turtles' ability to do so and therefore, should be removed. Natural prairie vegetation can be maintained on the site by periodic burnings before April or after October when the turtles are hibernating.

Nest predation appeared quite high. Although high nest predation is common for most turtle species, an effort should be made to reduce nest predation at the site to aid in the recovery of the population. Christiansen and Gallaway (1984) reported an increase in *K. flavescens* hatchling yield after racoons, the principle nest predators, were removed from the site. Coyotes and other mammalian predators inhabiting the

Henry Co. site should be removed periodically, in order to enhance the reproductive success of the mud turtles. Translocation of turtles in order to increase population size and/or to introduce new genetic stock to a population with a small gene pool may be one method of management. Translocation of adults has met limited success, as they try to return to their original ponds. Individuals appear to orient themselves with their surroundings, and recognize when they are not in their original home area. The translocated individual in this study (L1L2) did not remain in the pond where he was released, but instead returned to his original home range area. Moll (1980b) also suggested that mud turtles may be philopatric after a translocated adult female tried to return to her original home range some four miles away. Christiansen (pers. comm.) recommended translocating hatchlings to sites with dwindling or extinct populations, as they would imprint to the area in which they were released.

Recommendation of Preserve Size - With the exception of L1L2 and L3R3, all actual home ranges of the radio-tagged mud turtles are included in the 64 hectare area proposed for acquisition. The female L3R3 made an aestivation burrow only 1 m west of the west-boundary fence and a hibernation burrow 2 m to the west of this boundary. The male L1R2 made an aestivation burrow just 2 m to the north of the blacktop road that makes the north boundary of the site, and entered pond #1 to the north of this road. This individual may have been heading to the north to two smaller, less permanent ponds, when translocated. However, it is believed that he most likely would not have included these ponds in his normal home range. Figure 13 shows that the radius from the center of the pond complex which includes the

maximum distances moved by the mud turtles is 275 m. This is similar to results obtained by Moll (1988) in a radiotelemetry study of *K. flavescens* in Mason Co., Illinois, where the radius extended 225 m from the center and included all of the maximum distances moved by turtles from the water.

Most of the proposed 64 hectare area is included in the composite home range and therefor, should be of adequate size to support the majority of the population. Some emigration may occur to the north and to the east, but the bulk of the population would easily be protected in this area.

RECOMMENDATIONS

- 1) Purchase land from landowners. Minimum preserve size should include 32 hectares of the Frankenreider property and the adjacent 32 hectares of the Guthrie property. If possible, additional adjacent land should be purchased as a buffer zone.
- 2) Restore natural turf conditions to dunes on the Frankenreider tract by breaking up the sod and replanting with native shortgrass prairie bunch-forming grasses. Plowing should be done from November through February only.
- 3) Restore natural prairie vegetation. Trees and shrubs should be removed from the periphery of the ponds. Prescribed burnings should occur from November through February only.
- 4) Predator control. Periodic removal of mammalian predators (coyotes, foxes, racoons, skunks) is recommended to enhance nesting success.
- 5) Yellow mud turtle population should be sampled periodically to assess the recruitment of hatchlings. As a last resort, hatchlings could be translocated from

the population at Big Sand Mound, Iowa.

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APPENDIX A
Figures 1 - 16



FIG. 2. Aerial photograph of the study site (SEC 22, T16, R5E) in Henry Co., Illinois. 1 cm = 28.5 m.

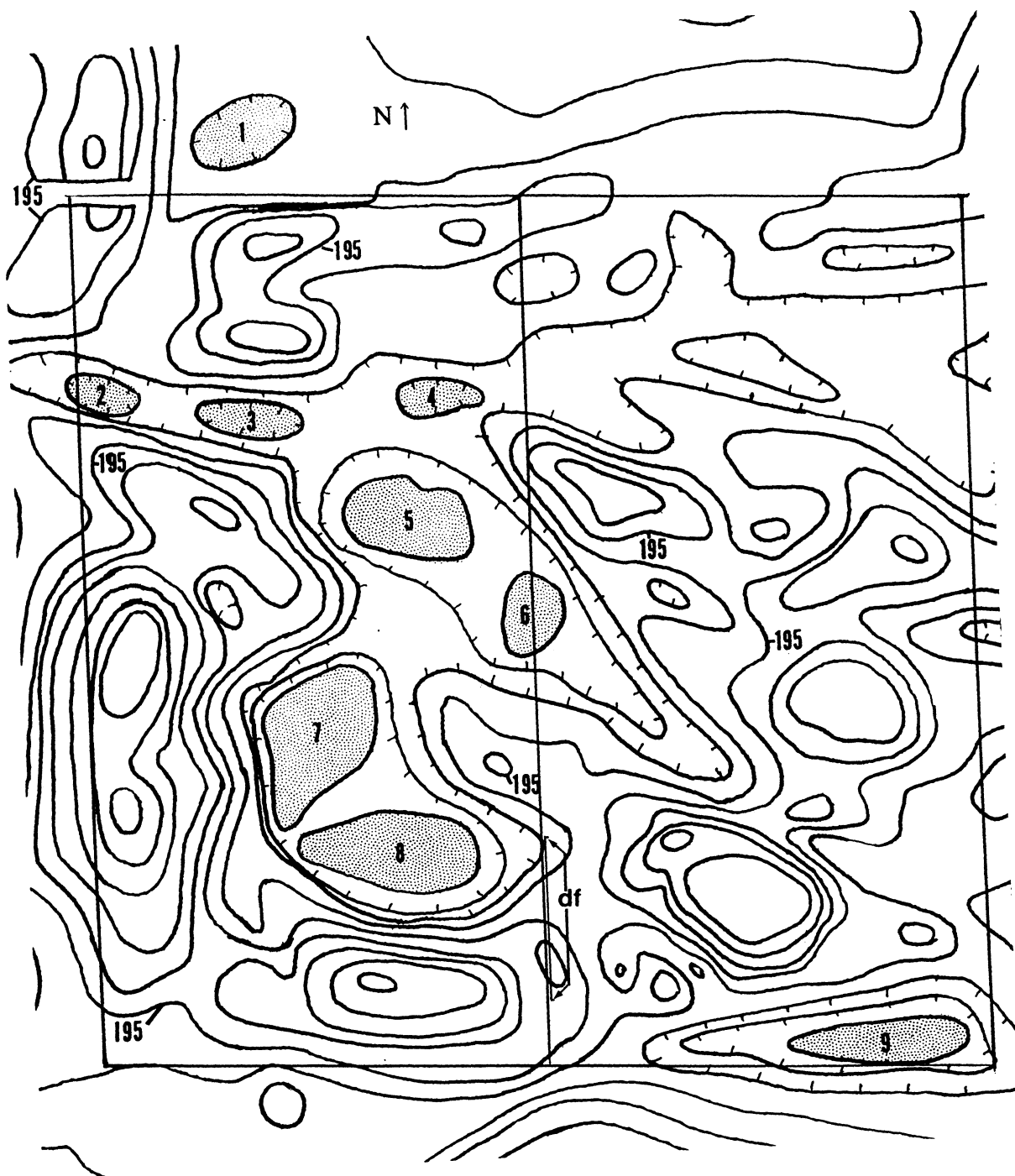


FIG. 3. Topographic map of the study site (SEC 22, T16, R5E) in Henry Co., Illinois. Contour intervals are indicated for 195 ft. The proposed area of acquisition for the preserve is enclosed by the rectangular areas; 32 hectares owned by Frankenreider (left), and 32 hectares owned by Guthrie (right). A 75 m section of drift fence was positioned along the border of the two properties and is indicated by df. Ponds that occurred during 1992 are labelled 1-9. 1 cm = 29.5 m.

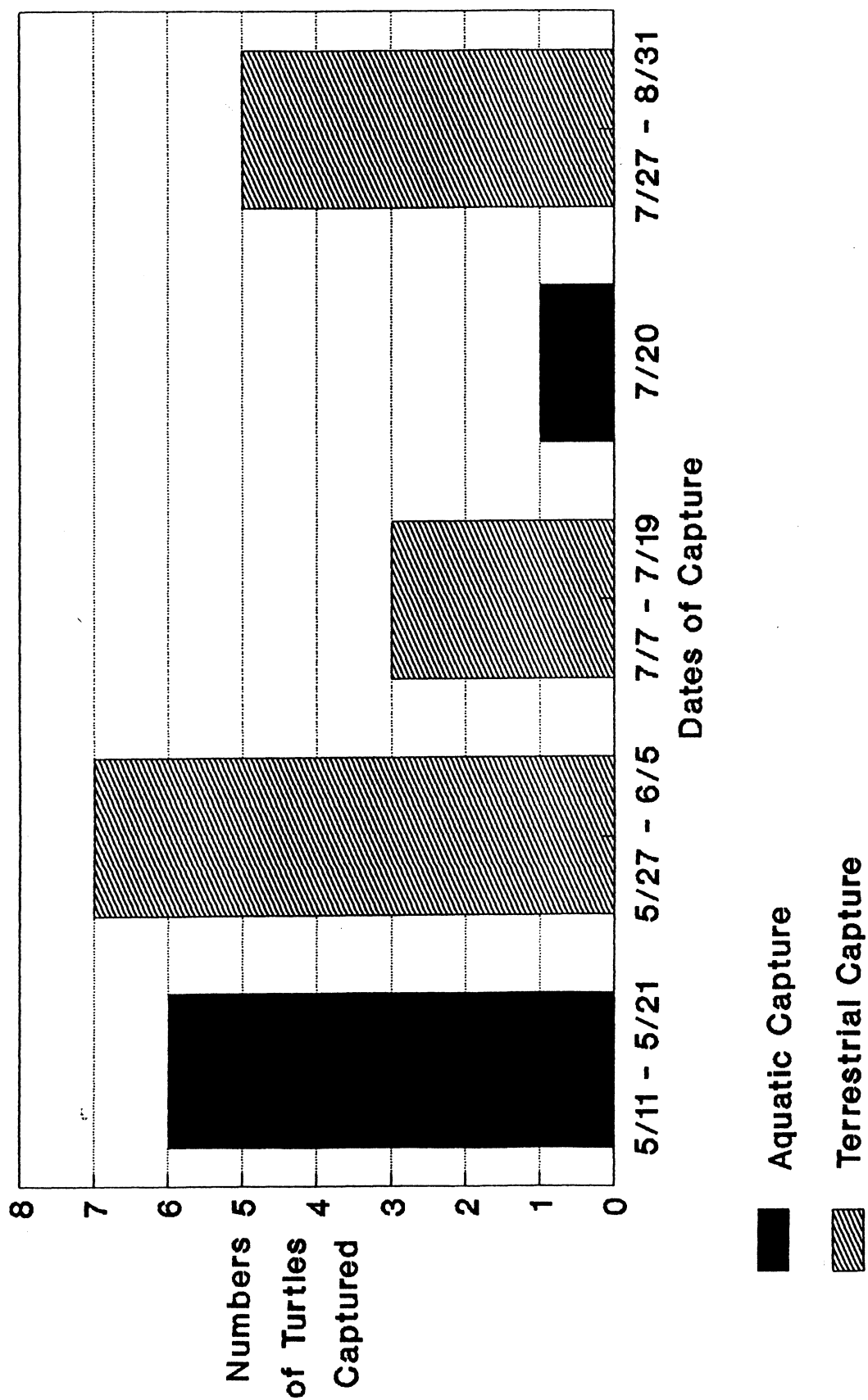


FIG. 4. Periodicity of captures for mud turtles > 1 year of age.

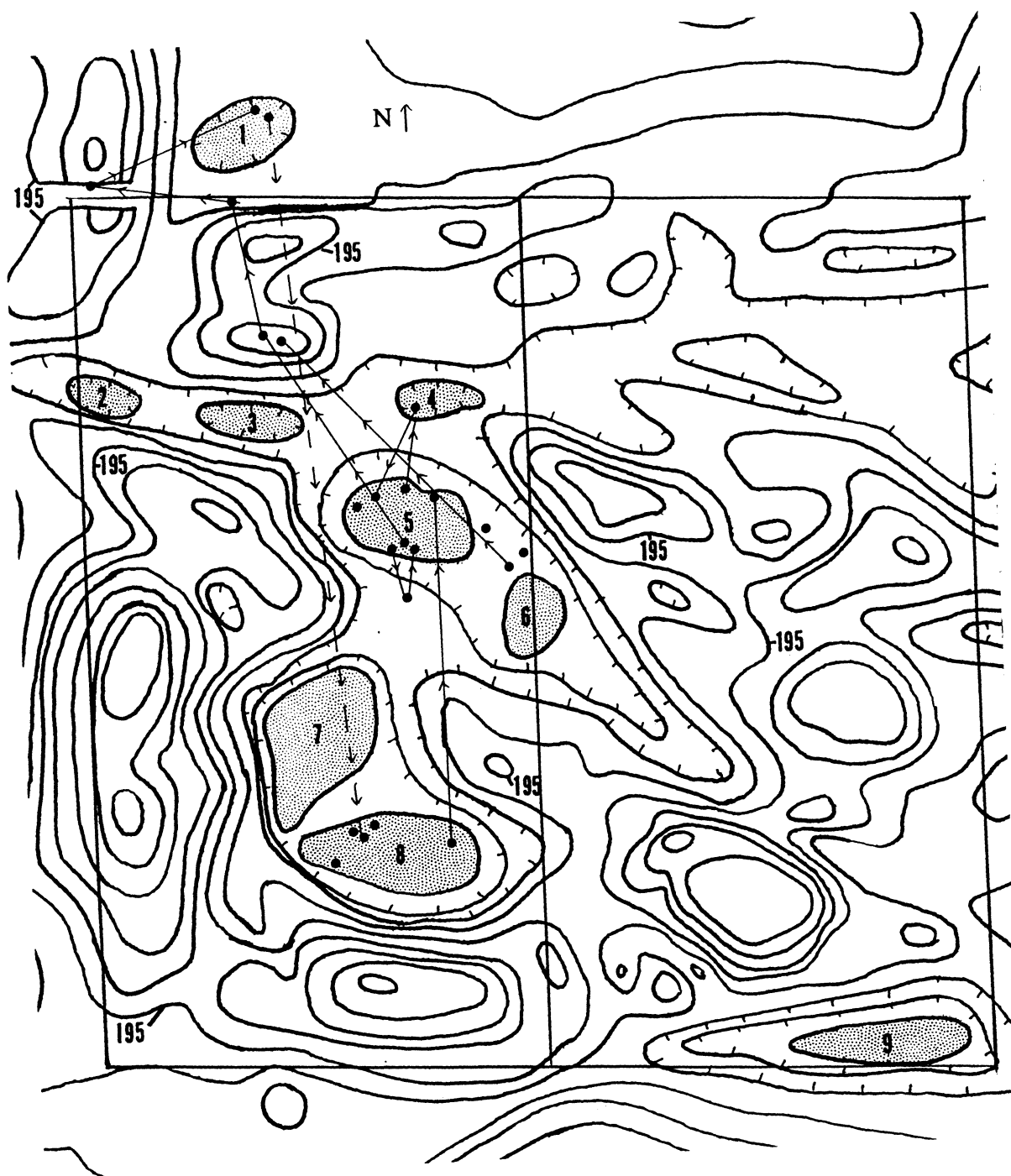


FIG. 5. Plotted locations for *K. flavescens* (L1L2). Translocation is indicated by the dashed line. 1 cm = 29.5 m.

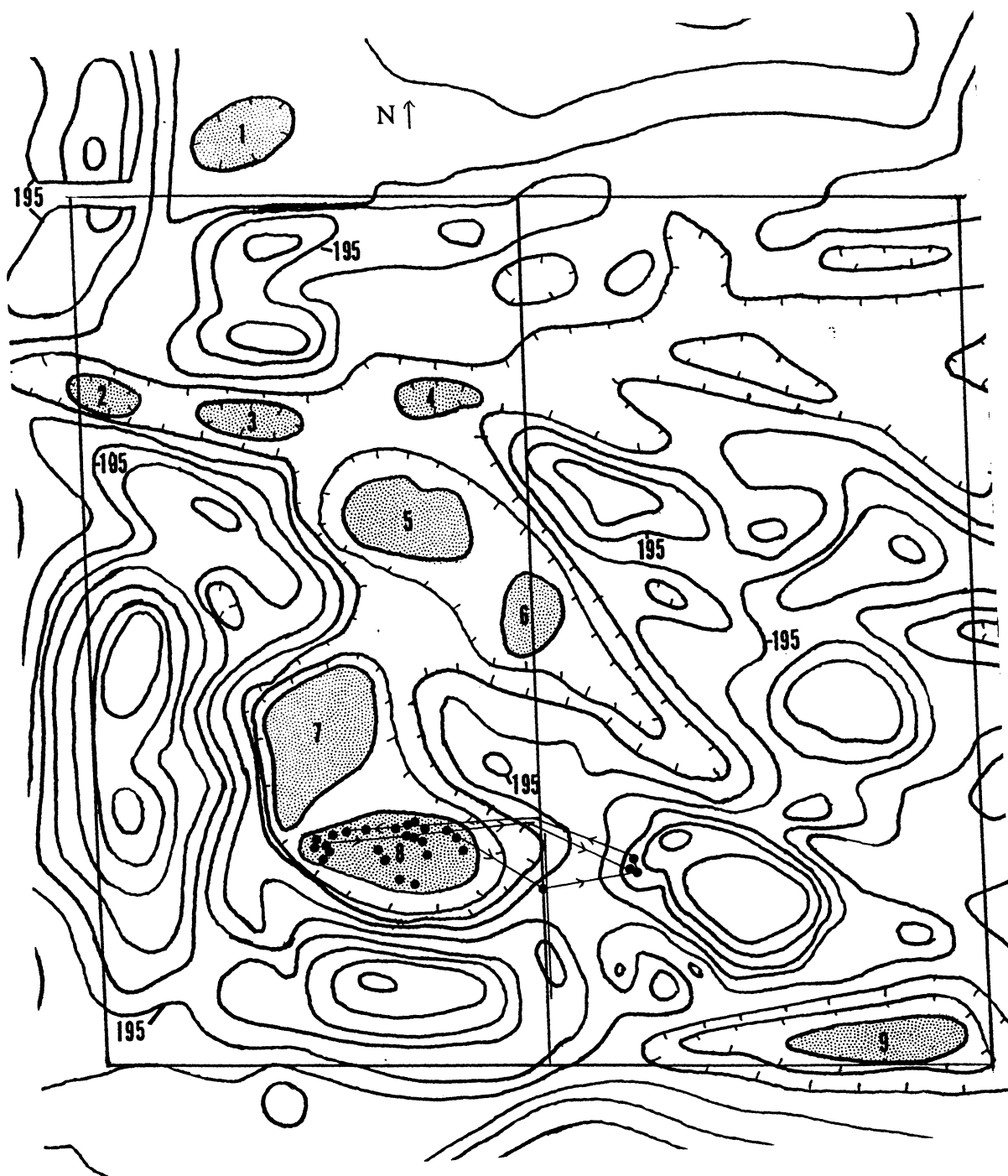


FIG. 6. Plotted locations for *K. flavescens* (L1L2L3). 1 cm = 29.5 m.

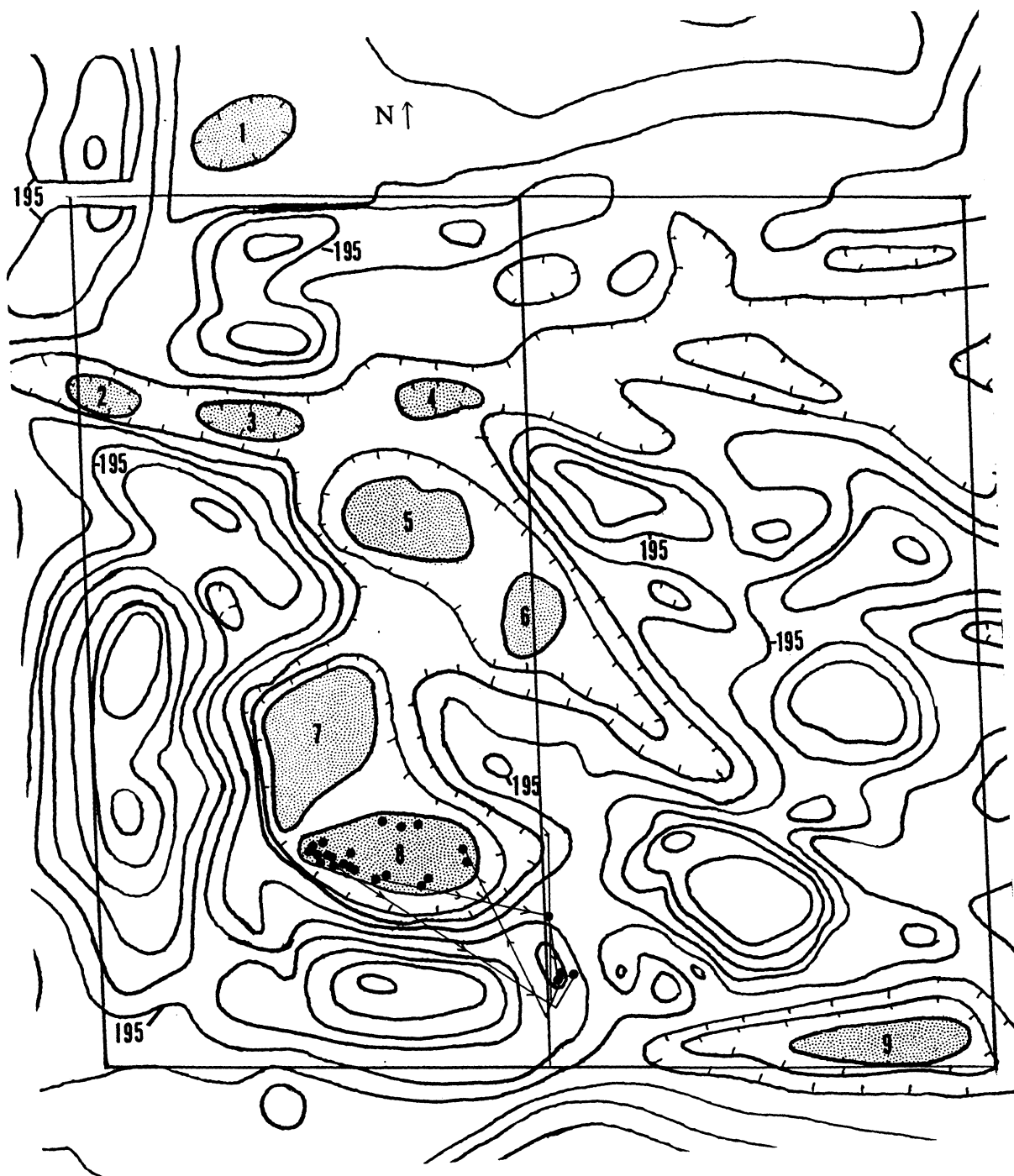


FIG. 7. Plotted locations for *K. flavescens* (L1R2). 1 cm = 29.5 m.

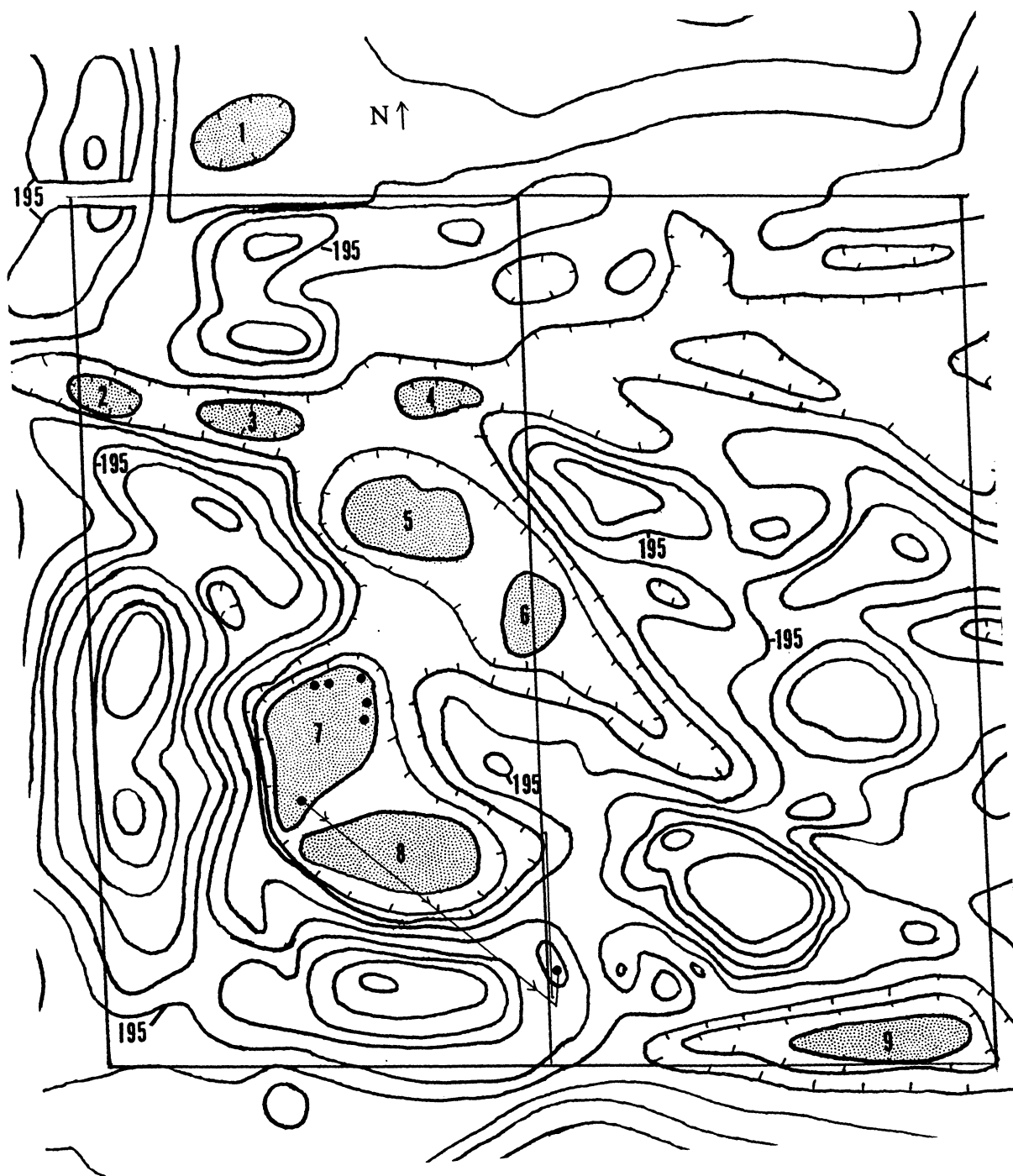


FIG. 8. Plotted locations for *K. flavescens* (L2R2). 1 cm = 29.5 m.

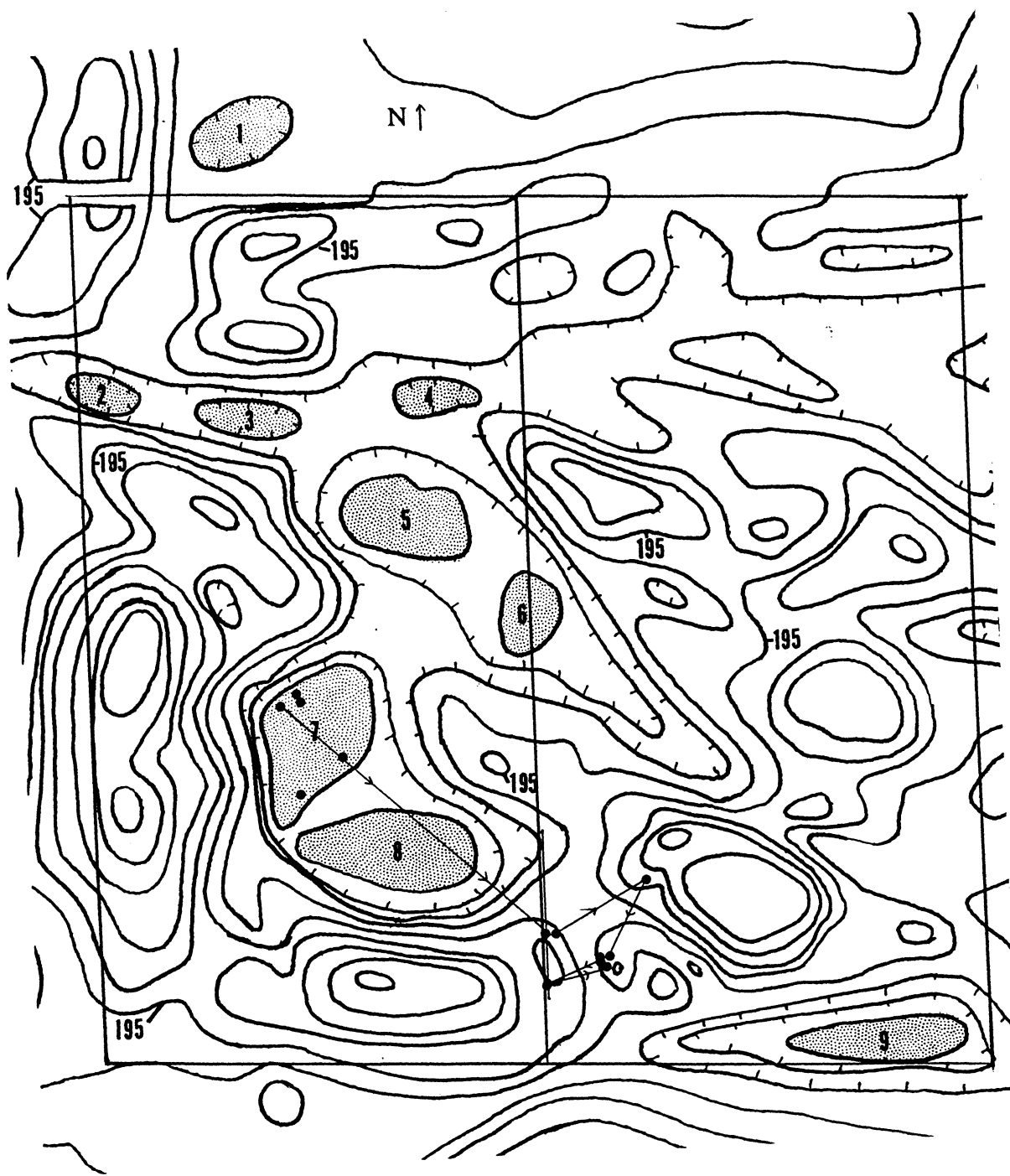


FIG. 9. Plotted locations for *K. flavescens* (L9). 1 cm = 29.5 m.

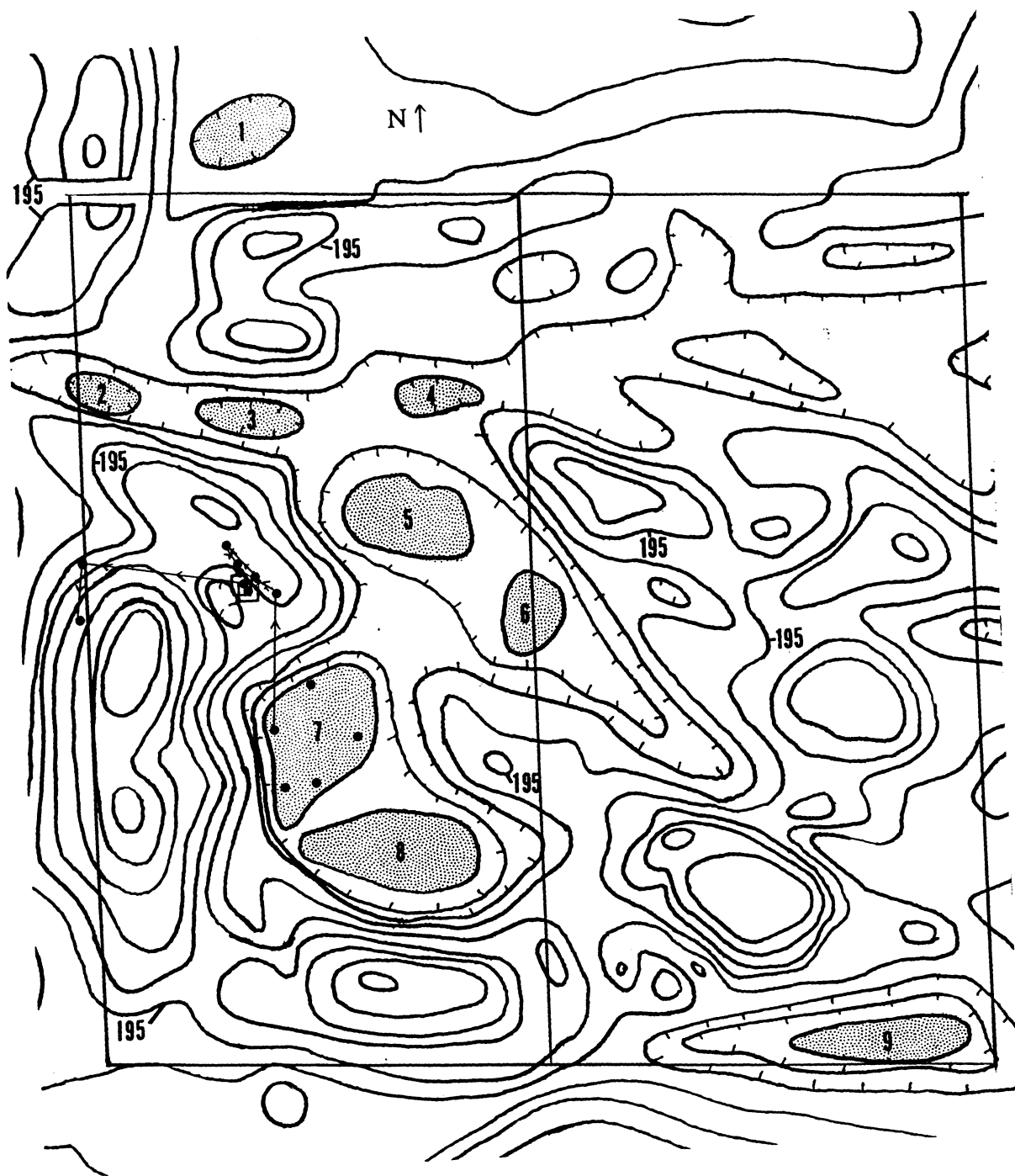


FIG. 10. Plotted locations for *K. flavescens* (L3R3). Nest sites are indicated by a square. 1 cm = 29.5 m.

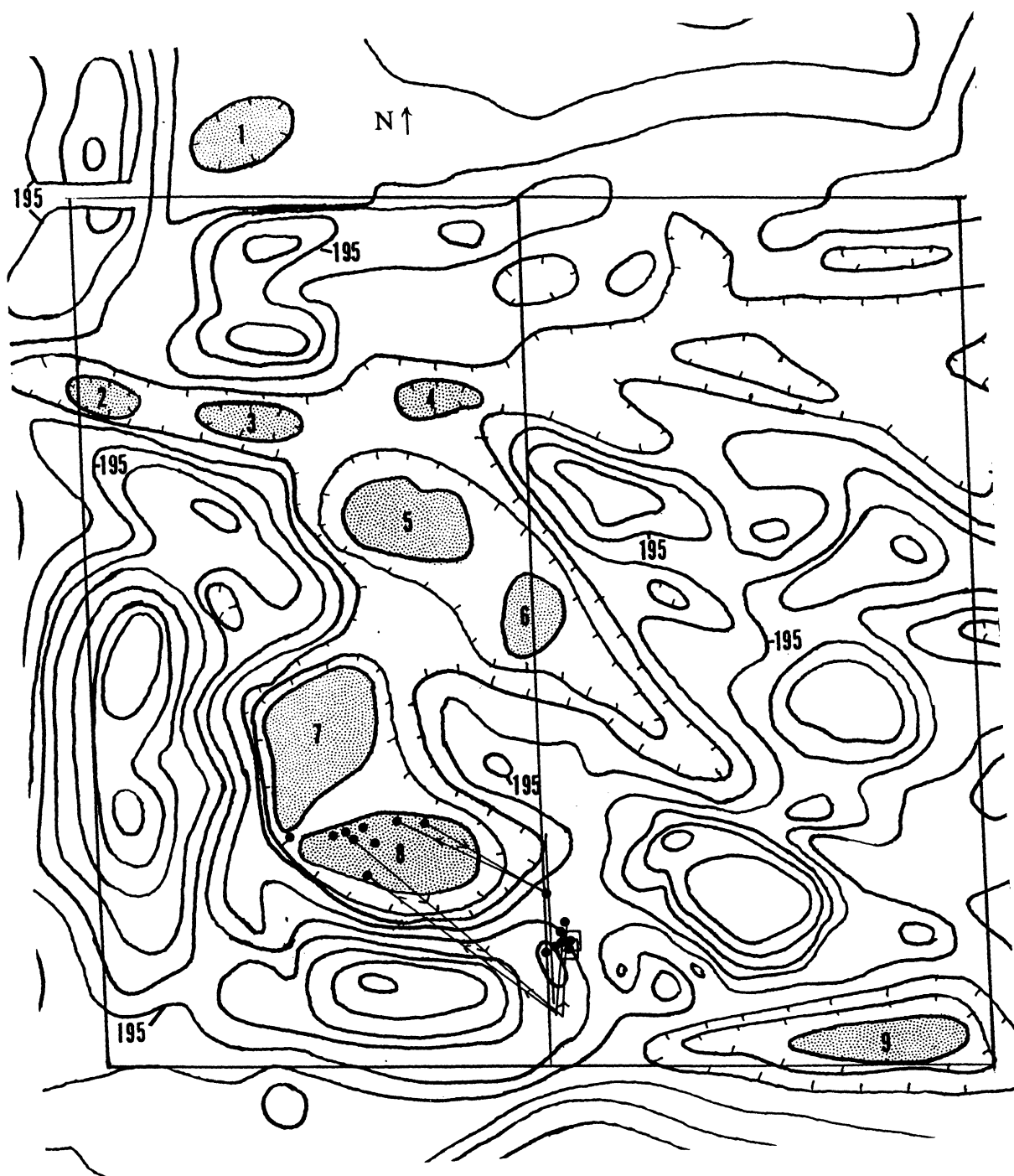


FIG. 11. Plotted locations for *K. flavescens* (L9R9). Nest sites are indicated by a square. 1 cm = 29.5 m.

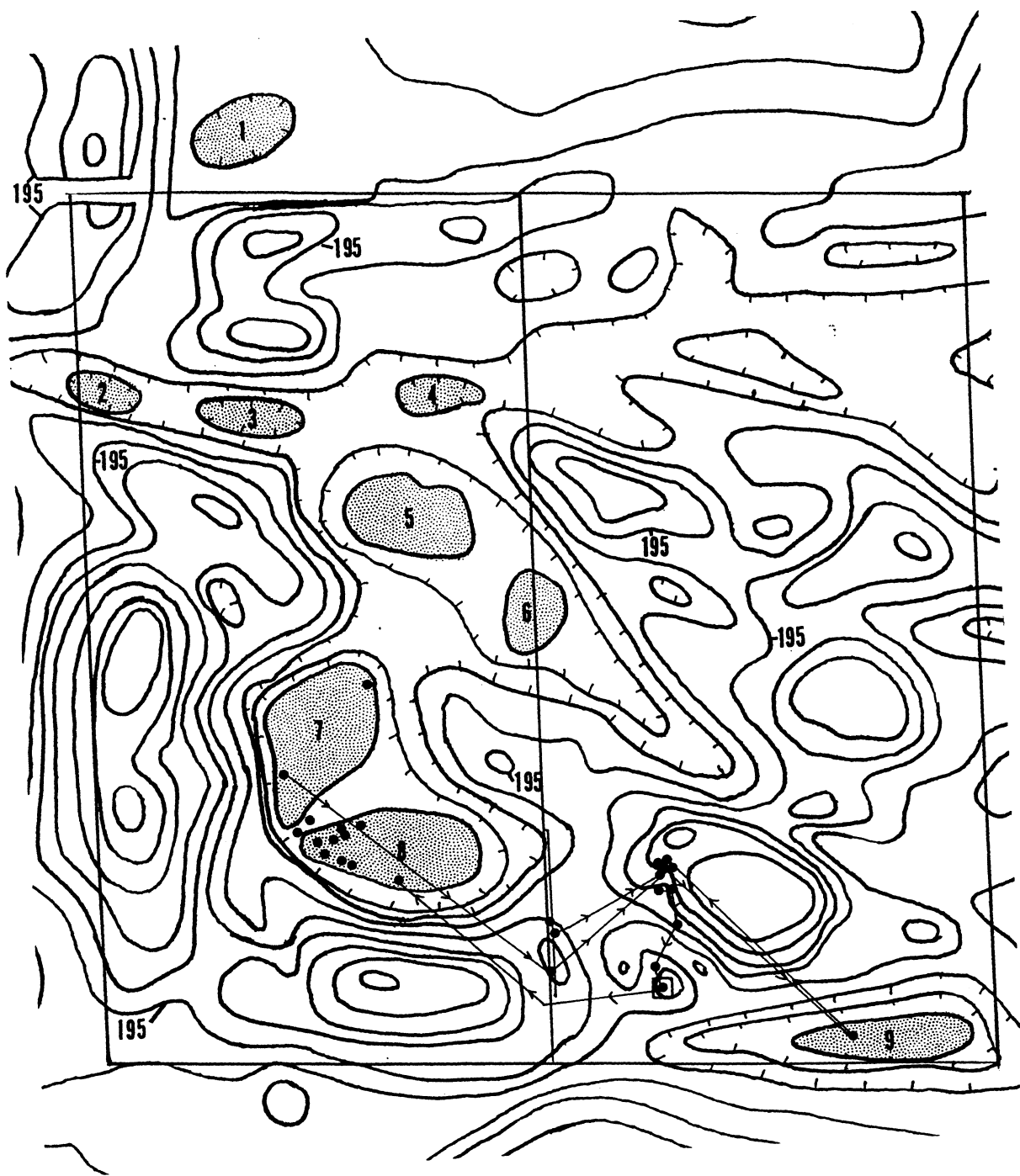


FIG. 12. Plotted locations for *K. flavescens* (L9R8). Nest sites are indicated by a square. 1 cm = 29.5 m.

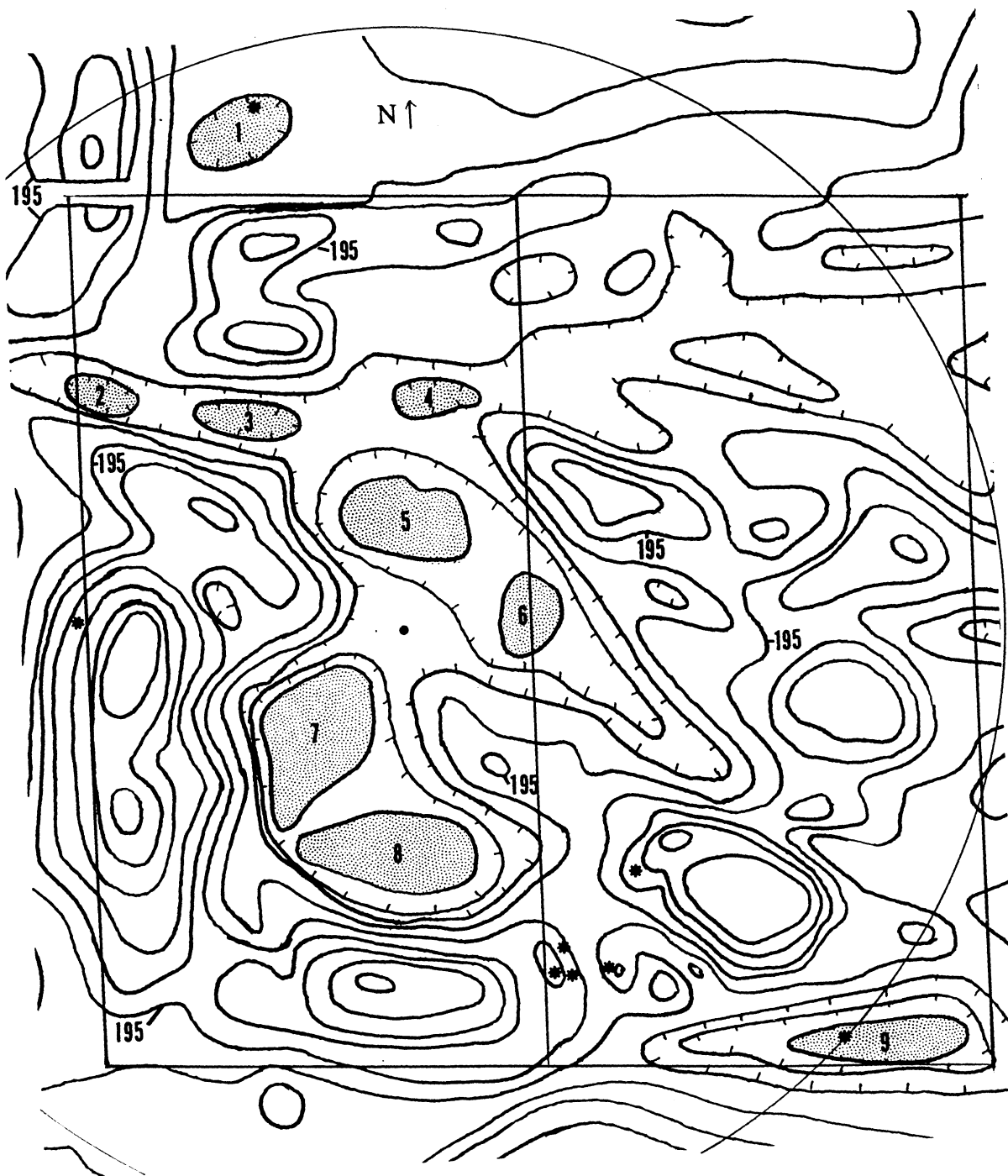


FIG. 13. Composite home range for all radio-tagged mud turtles as determined by the circular area encompassing all maximum locations moved by the turtles from their pond of central activity. The center of the circle is located in the center of the pond complex and the radius is 275 m. Maximum locations moved by the turtles are indicated by *. 1 cm = 29.5 m.

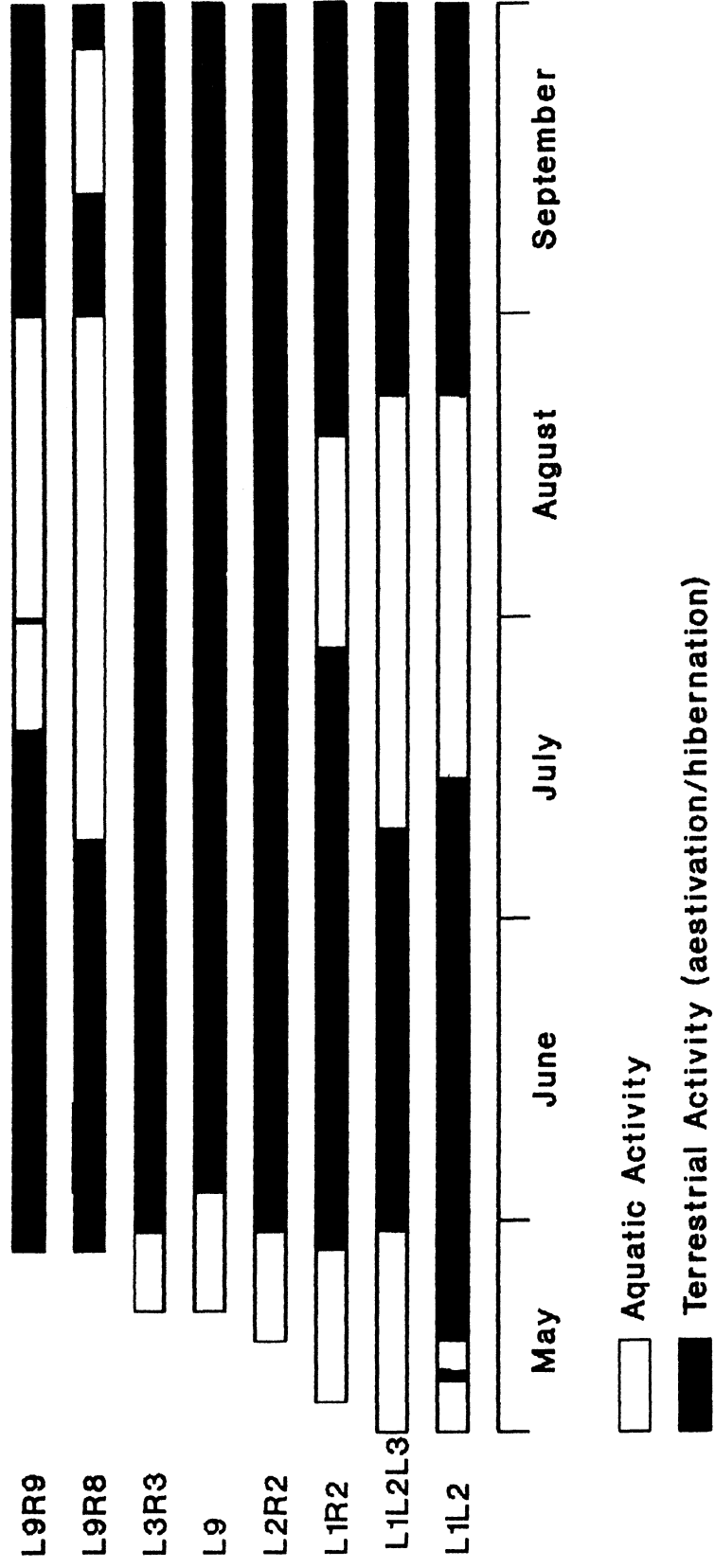


FIG. 14. Seasonal activity for radio-tagged mud turtles.

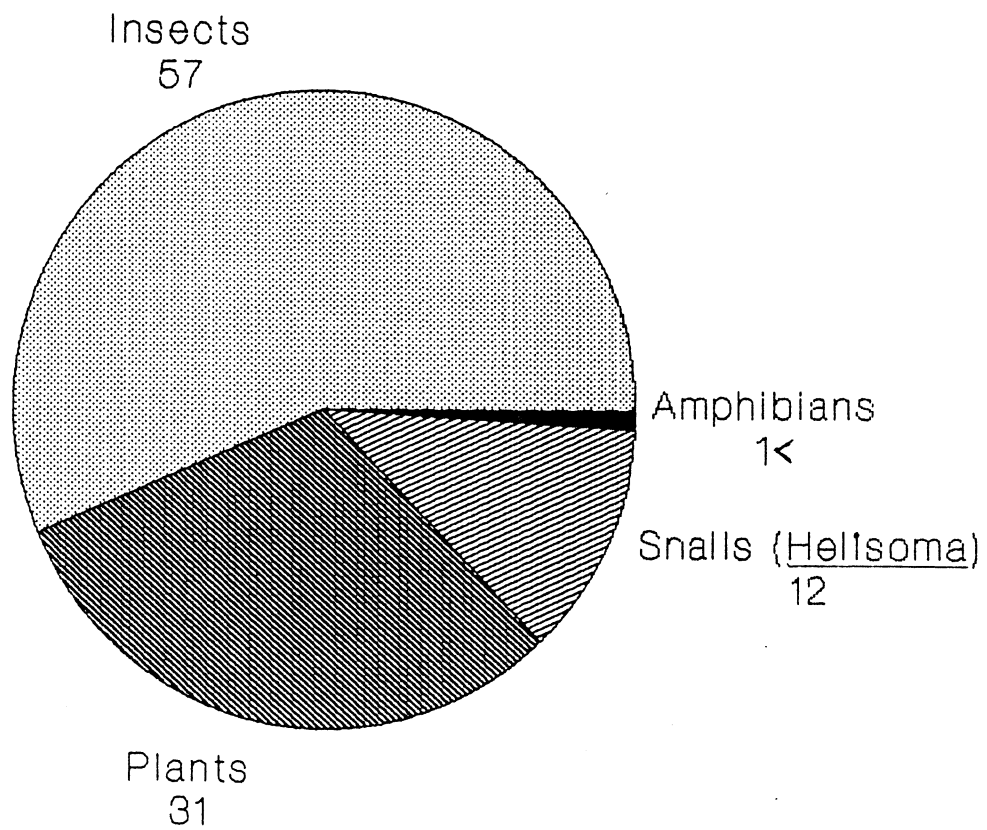


FIG. 15. Fecal sample analysis for 12 samples collected from *Kinosternon flavescens*. Numbers indicate mean % dry weight of all samples.

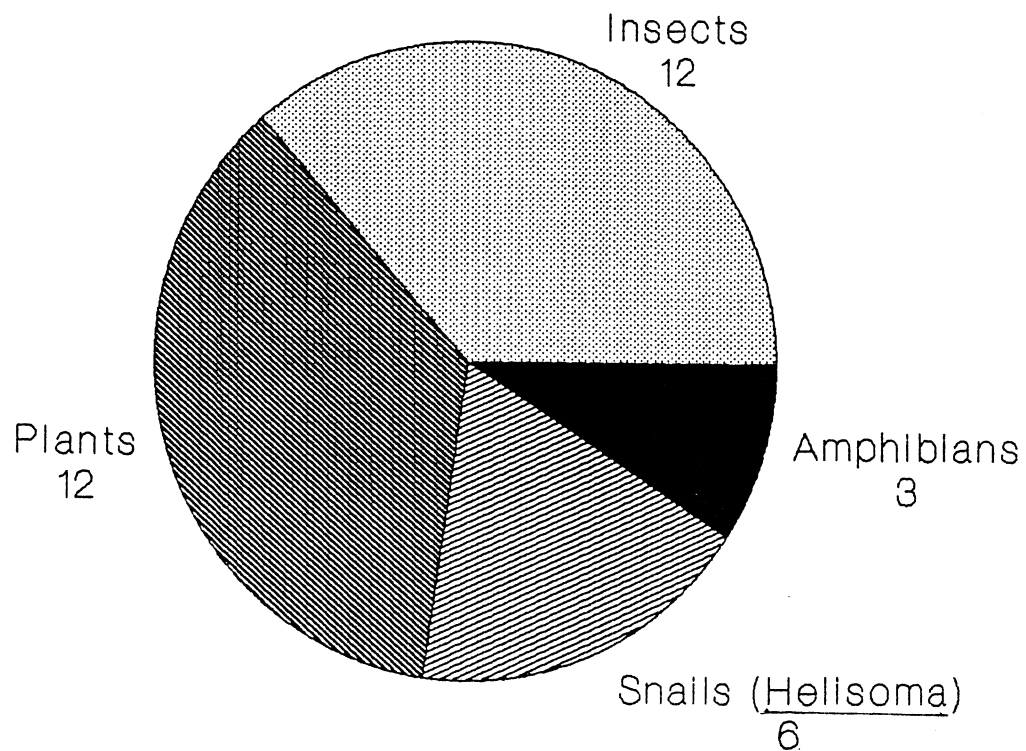


FIG. 16. Occurrence of food items in fecal samples collected from *Kinosternon flavescens*. Numbers indicate number of fecal samples out of 12 that contained the food item.

APPENDIX B
Tables 1 - 3

TABLE 1. Summary of turtle captures for 1992. * denotes radio-tagged turtle.

Species	#	sex	date of capture	method of capture	estimated age
* <i>K. flavescens</i>	L1L2	m	5-11-92	hoop trap	9
* <i>K. flavescens</i>	L1L2L3	m	5-11-92	hoop trap	11
<i>C. picta</i>	L1R12	juv	5-11-92	hoop trap	2
<i>C. picta</i>	L1L12	f	5-11-92	hoop trap	4
<i>C. picta</i>	L1	juv	5-11-92	hoop trap	2
<i>C. serpentina</i>	L10R10	f	5-12-92	hoop trap	4
<i>K. flavescens</i>	L1	juv	5-12-92	drift fence	hatchling
* <i>T. ornata</i>	L1	m	5-13-92	hand capture	12
<i>C. serpentina</i>	L10	f	5-13-92	hand capture	8
* <i>K. flavescens</i>	L1R2	m	5-14-92	hoop trap	10
<i>C. picta</i>	L1R1	juv	5-15-92	hoop trap	2
* <i>E. blandingii</i>	L3L9	m	5-16-92	hoop trap	15
<i>C. picta</i>	L1R3	juv	5-17-92	hoop trap	2
<i>C. picta</i>	L1L3R1	juv	5-19-92	hoop trap	2
* <i>C. picta</i>	L2R2	m	5-19-92	hoop trap	9
<i>C. picta</i>	L2R3	m	5-19-92	hoop trap	6
* <i>K. flavescens</i>	L2R2	m	5-19-92	hoop trap	8
<i>K. flavescens</i>	L2	juv	5-19-92	drift fence	hatchling
* <i>K. flavescens</i>	L9	m	5-21-92	hoop trap	12
* <i>K. flavescens</i>	L3R3	f	5-21-92	hoop trap	10
<i>C. picta</i>	L1R2	juv	5-22-92	hoop trap	2
<i>C. picta</i>	L10	juv	5-24-92	hoop trap	2
<i>K. flavescens</i>	L8R9	m	5-27-92	drift fence	9
* <i>K. flavescens</i>	L9R9	f	5-27-92	drift fence	12
* <i>K. flavescens</i>	L9R8	f	5-27-92	drift fence	10
<i>K. flavescens</i>	L8R8	juv	5-27-92	drift fence	2
<i>C. picta</i>	L3R1	juv	5-30-92	hoop trap	2
<i>C. picta</i>	L2R1	f	5-30-92	hoop trap	4
* <i>C. serpentina</i>	L3	juv	5-30-92	hoop trap	3
<i>C. serpentina</i>	L4	juv	6-02-92	hoop trap	3
<i>C. picta</i>	L2R3	juv	6-02-92	hoop trap	1
<i>K. flavescens</i>	R1R3	juv	6-02-92	drift fence	hatchling
<i>C. serpentina</i>	L5	juv	6-05-92	hoop trap	3
<i>K. flavescens</i>	L1L9	m	6-05-92	drift fence	8
<i>K. flavescens</i>	L2L9	juv	6-06-92	drift fence	hatchling
<i>C. serpentina</i>	L5R5	juv	6-10-92	hoop trap	2
<i>C. picta</i>	L3R2	juv	6-11-92	hand capture	hatchling
<i>K. flavescens</i>	L3L9	juv	6-14-92	hand capture	hatchling
<i>C. picta</i>	R8	f	6-23-92	hand capture	11
<i>K. flavescens</i>	L8R1	juv	6-30-92	drift fence	hatchling
* <i>K. flavescens</i>	L8R2	f	7-07-92	hand capture	8
<i>K. flavescens</i>	L8R3	m	7-13-92	drift fence	7
<i>K. flavescens</i>	L1L3	f	7-19-92	hand capture	7
<i>K. flavescens</i>	R8	f	7-20-92	hoop trap	16
<i>K. flavescens</i>	L1L8	f	7-27-92	drift fence	15
<i>K. flavescens</i>	L1L11	f	8-03-92	drift fence	10
<i>C. serpentina</i>	R3	m	8-04-92	hoop trap	4
<i>K. flavescens</i>	L9L10	juv	8-30-92	drift fence	1
<i>K. flavescens</i>	R9R10	juv	8-30-92	drift fence	1
<i>K. flavescens</i>	L9R10	juv	8-31-92	drift fence	1

TABLE 2. Maximum distances moved from pond of central activity for radio-tagged mud turtles.

Mud turtle #	Maximum distance
L1L2	408 m
L1L2L3	224 m
L1R2	190 m
L2R2	305 m
L9	354 m
L3R3	297 m
L9R9	194 m
L9R8	515 m
\bar{x}	311 m
s	105 m

TABLE 3. Fecal sample analysis for three species of aquatic turtles. Percent equals percentage of dry weight of identifiable remains in sample. Vertebrate remains equalled less than 1%. Sex of *Kinosternon flavescens* indicated by (m) or (f).

Species sample taken from	Date	% insect	% gastropod	% plant	Vertebrate remains
<i>K. flavescens</i> (m)	5-17-92	66.7	0	33.3	
<i>K. flavescens</i> (m)	5-17-92	58.8	14.7	26.5	
<i>K. flavescens</i> (m)	5-18-92	87.3	0	12.7	
<i>K. flavescens</i> (m)	5-20-92	38.4	34.6	27.0	anuran
<i>K. flavescens</i> (m)	5-20-92	31.9	6.4	61.7	
<i>K. flavescens</i> (m)	5-21-92	93.7	2.1	4.2	anuran
<i>K. flavescens</i> (f)	5-22-92	31.6	67.9	0.5	
<i>K. flavescens</i> (m)	5-30-92	78.9	0	21.1	
<i>K. flavescens</i> (m)	5-30-92	90.9	0	9.1	anuran
<i>K. flavescens</i> (m)	8-04-92	91.5	0	8.5	
<i>K. flavescens</i> (f)	8-04-92	29.5	23.1	47.4	
<i>K. flavescens</i> (m)	8-04-92	22.6	0	77.4	
<i>C. picta</i>	6-03-92	60.5	0	29.5	
<i>C. serpentina</i>	5-31-92	97.3	0	2.7	anuran
<i>C. serpentina</i>	6-10-92	93.1	0	6.9	anuran
<i>C. serpentina</i>	6-11 92	83.0	0	17.0	chelonian
<i>C. serpentina</i>	6-12-92	55.6	0	44.4	