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THE COMPARATIVE ECOLOGY OF THE KINOSTERNID TURTLES OF OKLAHOMA

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IBRAHIM YOUNIS MAHMOUD

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THE COMPARATIVE ECOLOGY OF THE KINOSTERNID TURTLES

OF OKLAHOMA

APPROVED BY

DISSERTATION COMMITTEE

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THE COMPARATIVE ECOLOGY OF THE KINOSTERNID TURTLES OF OKLAHOMA

CHAPTER I

INTRODUCTION

To a certain extent the comparative ecology and ethology of related allopatric and sympatric species have been neglected. The comparative study of related species and forms reveals similarities and differences in ecological requirements, some of which would be overlooked if each species were studied individually.

There are many descriptions of the life history and ecology of a single species or subspecies. During recent years, a few extensive studies in comparative ecology and ethology have appeared: Lorenz (1951) studied the comparative behavior of the Anatinae; Carpenter (1952) studied the comparative ecology of three garter snakes (Thamnophis) in mixed populations; Tinkle (1958) studied the comparative ecology of the turtle Sternothaerus carinatus complex; and

Winn (1958) studied the comparative reproductive behavior and ecology of fourteen species of darters (*Percidae*).

This investigation is a study of the comparative ecology of the kinosternid turtles of Oklahoma. They are represented by two genera and four species: *Sternothaerus carinatus carinatus*; *Sternothaerus odoratus*; *Kinosternon subrubrum hippocrepis*; and *Kinosternon flavescens flavescens* (*Chelydridae*; *Kinosterninae*). Both field and laboratory studies were conducted with these four species. The field study was primarily ecological, though some behavioral data were obtained, while the laboratory studies concerned both ecological and behavioral experiments.

Description

The distinguishing features of these four species are well described in the literature. However, additional morphological characteristics, previously overlooked, will be described here. The data on which these descriptions are based were collected throughout Oklahoma. Allowing for individual variation, these descriptions hold for 90 percent of the individuals of the four species.

K. s. hippocrepis

Throughout the geographical range of *K. s. hippocrepis* the carapace is usually smooth; its color is olive to dark olive. The plastron is reddish brown to dark brown, with the darkest color at the plastral sutures, becoming gradually lighter laterally until it reaches yellow around the outer edge of each plastral plate.

The young have two lateral longitudinal lines extending the length of the head. These lines break into spots or streaks as the animal becomes older or larger, fading away gradually. Posterior to the eye, in most individuals, there are yellow or brown spots on the dorsal, lateral or ventral portions of the head and the neck. Streaks or dots on the labial scutes of the male and female are brown to dark brown and yellow. These streaks and dots are often lacking in females but rarely lacking in males. Chin and throat barbels are present. Numerous minute neck barbels are sometimes present.

K. f. flavescens

The carapace is usually smooth but sometimes has a very rough surface; its color varies from light olive to olive-yellow or green. The plastron is entirely yellow in old individuals, reddish-brown bordering the sutures in young turtles, whereas in older individuals th.. entire plastron becomes yellow. Most of the males have dark brown spots on the lips, which are often lacking in the females. Barbels are present on the throat and the chin. Numerous minute neck barbels are also present.

In its western range, this turtle tends to be light in color, but becomes darker in color and smaller in size toward its eastern limits.

S. odoratus

The carapace is smooth, ranging in color from dark brown to olive brown. In the young, the plastron is generally maize except for the borders of the sutures, which are reddish-brown; however, this color fades with increasing age until the entire plastron becomes maize colored. On each side of the head in young turtles there are two distinct lateral yellow lines which break into spots and streaks as the animal becomes older and then fade away in the oldest individuals. In some individuals just posterior to the eye there is a transverse line connecting the two lateral lines on each side of the head. In the young turtles, these two yellow lines are frequently found on the dorsal side of the neck. There are yellow or brown spots on the dorsal and lateral parts of the head. Chin and throat barbels are present as are numerous minute neck barbels. This turtle tends to be smaller and darker toward its extreme western limit.

S. c. carinatus

The carapace has dark stripes or spots on an olive to brown background. These stripes and spots fade away gradually as the animal becomes older. In the young, the plastron is yellow, except for brown to dark brown at the borders of the sutures. This color gradually fades with age. The breadth of the sutures becomes wider with age. There are black to brown spots on the dorsal side of the head and neck which remain unchanged throughout life. Distinct black to brown spots on the labial scutes of the young gradually merge to solid brown or black in older individuals. The chin barbels are the only ones present.

Methods

The method of Cagle (1939) was followed in individually marking the turtles for future field identification. For the large turtles, a rat-tail file was used to notch the marginal plates, while a sharp scalpel or razor blade was used for juveniles.

Turtles were captured by hand, with a dip net, by trapping, and by Carpenter's (1955) sounding technique. Water turbidity and depth were factors determining the collecting method In shallow or clear water, usually hand or dip net methods were used, while in turbid or very deep water, trapping was the most productive method.

A trap consisted of a wooden frame covered with a one-inch mesh wire screen. These traps were rectangular with a funnel leading in at each end and were to two sizes: 2½ feet by 1 foot and 4 feet by 2 feet. Meat scraps or freshly killed animals were used for bait.

Each of the four species was studied separately in its typical habitat. The study area for each species was mapped. Also, turtles were captured and observations were made in the overlapping zone of *K. s. hippocrepis*, *S. odoratus* and *S. c. carinatus*.

The time spent and the number of turtles found in each locality of each study area were recorded at the end of each visit. Each study area was visited at different times during the 24 hour periods and at different times during the year in order to determine the daily and the annual cycle of the turtles. It was not practical to spend equal time and effort in each locality.

The collecting methods used for each of the study areas depended on the physical conditions. If sounding, hand or dip-net methods were used, then the method of searching was walking the bank or wading. If trapping was used, then the traps were checked at each time interval and they were set at different localities throughout the study area.

When the turtles were captured the following information was recorded: type of activity, point of capture, reactions when handled, coloration, time of capture, sex, algal growth on the carapace, and the measurements which included the length, width and height of the carapace.

The cloacal temperature was taken as soon as the turtle was captured by hand or dip-net. Air and water temperatures were taken at all points of capture. A Schultheis thermometer (Bogert, 1949) was used to take the cloacal temperatures. Fecal droppings were brought to the laboratory for identification.

Extended field observations were conducted when possible on feeding, basking, courtship, and mating habits. These observations lasted from a few minutes to a few hours depending on the type of activity and the habitat conditions.

Study Areas

The following areas were chosen for study: Cowan Creek and Lake Texoma for *Kinosternon subrubrum hippocrepis*; Berry's Pond, the Oliver Wildlife Preserve and Donita's Pond for *Kinosternon flavescens flavescens*, Honey Creek for *Sternothaerus odoratus*, and the Mountain Fork River for *Sternothaerus carinatus carinatus*. Additional ecological data were collected at random throughout the state.

From 1956 to 1959, 1,292 records were obtained for 911 kinosternid turtles of which 26 percent were *K. s. hippocrepis*, 34 percent were *K. f. flavescens*, 29 percent were *S. odoratus*, and 11 percent were *S. c. carinatus*.

Cowan Creek

This creek was located one mile west of Willis, Marshall County, Oklahoma, in the post oak-blackjack association. During this study the creek normally varied from one to two inches deep and five to ten feet in width and had a sandy and muddy bottom. About 40 small springs were located along its one mile length (1.24 acres). Except for the lower end, this creek was in a gully about 20 feet deep and shaded with overhanging trees (map 1). The current varied from one to three feet per second. Aquatic plants were very sparse throughout the creek except near its mouth where Nasturtium officinale was very abundant. The creek flowed southward into Lake Texoma and, just before it emptied into the lake, it became wider and deeper. This creek flowed all year.

Honey Creek

Honey Creek (map 2) was formed by several springs in the Arbuckle Mountains and flowed northeastward for about 15 miles into the Washita River in Murray County. The study area in this creek was located about eight miles southwest of Davis, Murray County, Oklahoma. The 6.4 acre area studied extended over one half mile and was located above Turner Falls situated on this creek.

Honey Creek was characterized by clear water, abundant aquatic plants, bed rocks to sand and gravel bottom, riffles, and quiet pools. The current varied from one to five feet per second. The dominant aquatic plants were Chara and Myriophyllum, which usually formed mats on the water surface of quiet pools where most of the turtles were found. The average depth was three feet and the width averaged about 30 feet. Honey Creek wound through the post oak-blackjack association in the area studied; however, the upper end of Honey Creek was located in the tall grass prairie association. This creek flowed throughout the year.

Mountain Fork River

The Mountain Fork River headed in the Kiamichi Mountains, flowed southward through Le Flore and McCurtain Counties, Oklahoma, and Polk County, Arkansas, and emptied into Little River. The length was about 90 miles.

The study area of approximately five acres extended about half a mile south of the dam in Beavers Bend State Park, McCurtain County, Oklahoma, and was located in the oak-pine association (map 3). The dominant vegetation consisted of *Pinus echinata*, *Quercus nigra*, *Quercus falcata* and *Carya tomentosa*. Aquatic plants in the river were very sparse; those present were *Chara* and *Salix*. The bottom type consisted of rock, sand and gravel. Other physical characteristics of the study area were moderate turbidity, riffle and pool formations and slow current (about 4 feet per second). The average depth was three and a half feet while the width was 120 feet.

Donita's Pond

The pond was located about five and one half miles west of Garber and ten miles south of Hunter, Garfield County, Oklahoma. This one-acre pond was in the tall grass association. Dominant aquatic plants were Najas quadalupensis, Potamogeston nodosus and Chara sp. Physically it had a very high turbidity, was one to six feet deep, and of a soft mud bottom.

This farm pond was built in 1926. The water was permanent, being supplied by run-off rain water. The water level became low only during extended drought.

Berry's Pond

This 9.2 acre pond (map 4) was located in the tall prairie association about five miles north of Norman and one mile south of Moore, Cleveland County, Oklahoma. Its water source was run-off rain water. The dominant aquatic plants were Najas quadalupensis, Potamogeton nodosus, and Chara which formed mats over most of the shallow areas of the pond. The turbidity and bottom type were similar to those of Donita's Pond. Water depth varied between 1 and 20 feet. Willows were very abundant along the northeast shore of the pond.

This man-made pond was built in 1946 and has held water continuously.

Oliver Wildlife Preserve

This 60 acre preserve was located two miles south of Norman, Cleveland County, Oklahoma on the flood plain of the Canadian River. Penfound (1948) stated that the cottonwood trees in this preserve were being replaced by American elm, green ash and persimmon.

After several consecutive rains, an area of about seven acres on the north section of the preserve was frequently covered by water averaging one foot in depth. The turtles were very active throughout this area. However, after this high water receded, the turtles confined their activities to six small pools on the north side of the preserve.

CHAPTER II

HABITAT

The four species were studied in their natural habitats and in the laboratory to determine their ecological requirements. Information recorded concerned the types of water bodies, submerged vegetation, water current, water turbidity, water depth, bottom type, and light intensity, where possible. Differences and similarities in the habitat selections of the four species were revealed when these data were analyzed (figs. 1-6).

Although unequal amounts of time and effort were spent in various localities, the investigator felt that sufficient field observations and records were gathered to give adequate information relative to the habitat preferences.

Permanent bodies of water in wooded areas were the preferred habitats of *S. c. carinatus*, *S. odoratus*, and most of the *K. s. hippocrepis* (fig. 2). Although temporary bodies of water occurred throughout the eastern half of the state, S. c. carinatus and S. odoratus were never found in them and K. s. hippocrepis very seldom.

Risley (1933) reported finding S. odoratus in lakes and rivers around Ann Arbor, Michigan. Cahn (1937) found S. odoratus occurring in lakes and rivers, but more abundantly in the Illinois River than in any other aquatic habitat within Illinois. Cagle et al. (1950) found S. odoratus, S. c. carinatus and K. s. hippocrepis in rivers and lakes in Louisiana. Tinkle (1958) reported that S. c. carinatus was found in running water or permanent bodies of water connected with running water.

In this study S. odoratus and S. c. carinatus were seldom observed in lentic habitats in Oklahoma. The absence of suitable lakes in Oklahoma may be responsible for this.

In this study K. s. hippocrepis was found living in various habitats (fig. 1), but showed a definite preference for those with a sandy-muddy bottom (fig. 3) and for waters of medium turbidity (fig. 4).

K. s. hippocrepis was found in shallow spring-fed creeks, the water depth ranging from 1 inch to 10 inches. The preferred water current ranged from 2 to 4 feet per second. The dominant aquatic vegetation was Nasturtium officinale.

In large lakes (fig. 1), K. s. hippocrepis was found mostly in small bays and inlets and near the shore where the water was quiet and where there was an abundance of overhanging willows. Water depths here ranged from 1 to 5 feet. Submerged vegetation was rare except in a few inlets where mats of Chara sp. and Najas quadalupensis were found.

In highly vegetated farm ponds and in fish-hatchery ponds, this species was found in water depths ranging from 1 to 5 feet. The dominant aquatic plants were Najas quadalupensis, Potamogeton nodosus and Chara sp.

In shallow spring-fed sloughs, this species preferred a water depth ranging from 1 to 5 inches. The dominant submerged vegetation was Nasturtium officinale.

In large rivers and creeks they showed a preference for a water depth ranging from 1 to 5 feet, and for a water current of 1 to 4 feet per second. The dominant aquatic plants were Chara, Nasturtium, Polygonum and Myriophylum.

S. odoratus was found in lotic habitat such as large rivers and creeks with a rocky, gravel or sandy bottom (fig. 3) and water of low turbidity (fig. 4). The dominant submerged plants were Chara, Nasturtium, Polygonum and Myriophylum. The preferred water depth ranged from 1 to 5 feet and the water current from 1 to 4 feet per second.

S. c. carinatus, in many respects, has a habitat similar to that of *S. odoratus* (figs. 1-6). However, *S. c. carinatus* was generally found in deeper water. The preferred water depth ranged from 2 to 6 feet. Sunlight was sought more by this species than by *S. odoratus*.

K. s. hippocrepis, *S. odoratus*, and *S. c. carinatus* were frequently found together in large rivers where trapping records showed that each of the three species was relatively equal in abundance.

In contrast to the other three species, *K. f. flavescens* showed a strong tendency for temporary lentic habitats located in the grasslands of the western half of the state (fig. 6). Although lotic habitats were also found in this half of the state, this turtle was never taken from this type of habitat. The preferred water depth ranged from 1 to 10 feet. The dominant submerged plants were *Najas quadalupensis*, *Potamogeton nodosus*, and *Chara* sp.

Farm ponds were one of the preferred habitats of *K. f. flavescens* (fig. 1). Most of these were permanent ponds except during extended drought when some of them dry up. Before these farm ponds were made, most of the aquatic habitats of this species probably consisted of temporary bodies of water, such as playas and "buffalo wallows." With the construction of farm ponds, a habitat niche was created causing a possible increase in the number of individuals of this species.

K. f. flavescens was the least aquatic and the most migratory of the four. S. odoratus and S. c. carinatus were strictly aquatic species; terrestrial migrations occurred only during the breeding season. K. s. hippocrepis was a strictly aquatic species except in farm ponds, where some migratory habits were observed.

Several laboratory experiments were conducted to test the habitat selection for the four species. A concrete tank was divided into two equal sections by a wooden partition with a passage near the bottom of the tank to allow the turtles to pass freely from one section to the other. Six individuals for each species were used for each experiment.

Bottom Selection (1). The bottom of each compartment of the tank was covered with sand or gravel. Water depth was kept at 6 inches. The tank was visited 98 times. During each visit a record was made of the number of individuals of each species in each half of the tank. Table 1 indicates that each species preferred that type of bottom similar to that of its natural habitat (fig. 3).

Light Reaction (2). A small light bulb (10 watts) was placed at one half of the tank only. All observations were made during the night when the tank-room was completely dark except for the lighted half of the concrete tank. A total of 159 observations were made during which the number of individuals of each species at the light or dark side was recorded. The results of this experiment indicated definite correlations with the natural habitat of each of the four species. The natural habitat of *K. f. flavescens* is in grassland areas, where the light intensity is at its highest and this species (table 1) in this tank experiment showed a positive phototaxis compared to the other three. *K. s. hippocrepis*, which occurs naturally in wooded areas and grassland-forest ecetones demonstrated a slight preference for light. *S. odoratus* and *S. c. carinatus*, which occur naturally in wooded habitats, were the least attracted by the light.

Water Current (*3*). In one half of the divided tank, a water faucet was kept running, producing a swift current, while in the other half the water was kept relatively quiet. About 200 observations showed that 95 percent of the individuals of each of the four species preferred quiet water.

Water Depth (*4*). The water in the concrete tank was kept at different depths over several trials, in order to determine the optimum depth for feeding, courtship and mating. These activities were seen more often in *K. s. hippocrepis* and *K. f. flavescens* when the water depth was at 6 inches while in *S. c. carinatus* and *S. odoratus* these activities increased when the water depth was above 2 feet.

Vegetational Preferences (5). Aquatic plants *Najas quadalupensis*, *Potamogeton nodosus*, and *Chara* were placed in one half of a concrete tank in which the water depth was kept at 5 inches. Individuals of the four species chose the vegetated half of the tank in each of the 200 observations.

The experiments on bottom selection (exp. 1) water current (exp. 3), and light (exp. 2) were set up together in the tank in order to determine the most limiting ecological factor. About 200 observations showed that the four species preferred the quiet water regardless of the light or bottom conditions.

From the field and laboratory data, it appeared that the four species preferred quiet water, since they were seldom found in current which exceeded 5 feet per second. No turtles were seen or collected from an aquatic habitat with a swift current.

Temporary and permanent bodies of water, water depths, bottom types and the degrees of turbidity are the ecological factors which separate K. f. flavescens from the other three species (which sometimes live together).

There are more of the permanent types of water bodies in the eastern part and more of the temporary types in the western part of Oklahoma. From the data in figure 2 it appears that a temporary or permanent body of water is probably an important factor in the ecological and geographical separation of the four species.

The field observations showed that water depth was more critical to S. odoratus and S. c. carinatus than to K. f. flavescens and K. s. hippocrepis. The latter species were found in water depths ranging from one half inch to several feet in different localities and habitats. The greatest water depths recorded for K. s. hippocrepis and K. f. flavescens were 15 and 12 feet respectively. For S. odoratus and S. c. carinatus water depth, generally, was greater than one foot. The greatest water depth recorded for the latter two species was approximately 20 feet. Carr (1952) said "In the clear Florida springs I have often seen them in water thirty feet deep and slightly more." The size of the aquatic habitat may be an important factor since large rivers and creeks were preferred by S. odoratus and S. c. carinatus.

Individuals of _K. s. hippocrepis_ and _K. f. flavescens_ which were collected from sandy and muddy bottoms showed an algal growth, mostly of _Basicladia_, concentrated on the posterior one third of the carapace. On the other hand _Basicladia_ was distributed over the entire carapace of _S. odoratus_ and _S. c. carinatus_. Proctor (1958) said that the "scouring action that results from burrowing would be most effective on the forepart of the carapace where it apparently prevents the effective colonization of the shell by _Basicladia_." Individuals of _K. f. flavescens_ and _K. s. hippocrepis_ were found to borrow into mud and sand and because of the burrowing habit, the investigator felt that sandy or muddy bottoms were an important habitat requirement. In contrast, _S. odoratus_ and _S. c. carinatus_, which did not show burrowing proclivities, preferred rocky and gravel bottoms. When inactive, _S. odoratus_ and _S. c. carinatus_ hid under rocks, logs, and overhanging banks.

Since _S. odoratus_, _S. c. carinatus_, and _K. s. hippocrepis_ were found to be associated with water of low to medium turbidity, it may be that this ecological factor was a limiting factor in their habitat distribution. _K. f. flavescens_ was found mostly in water of high turbidity.

Light intensity was not an important requirement in the habitat selections even though it varied within the habitats of the four species. To a certain degree, all of them showed negative phototaxis. Basking in the sun is very rare in the four species. Proctor (1958) said that "Basicladia may be less common on turtles that bask almost continuously out of water." Basicladia was found commonly on the four species studied here.

Within the four species studied there were no sexual, age, or seasonal differences observed in the habitat selections, except that the juveniles of the four species preferred shallower water than the adults.

Although the four species showed some difference in habitat preference, they all showed a preference for quiet shallow water with an abundance of submerged vegetation.

Figure 1

A comparison of the percentage of captures from various aquatic habitats for four species of kinosternid turtles in Oklahoma, 1956-1959.

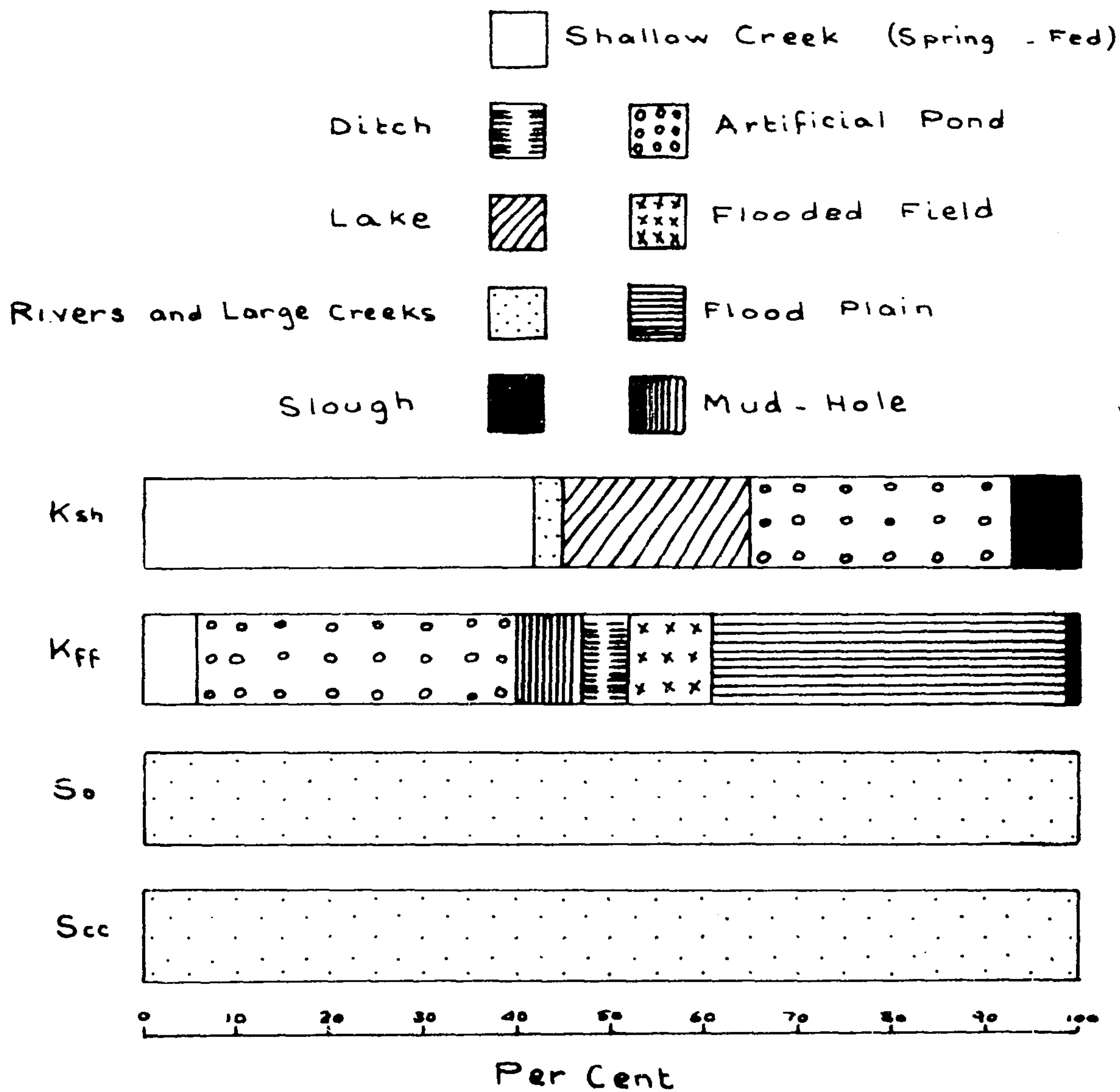
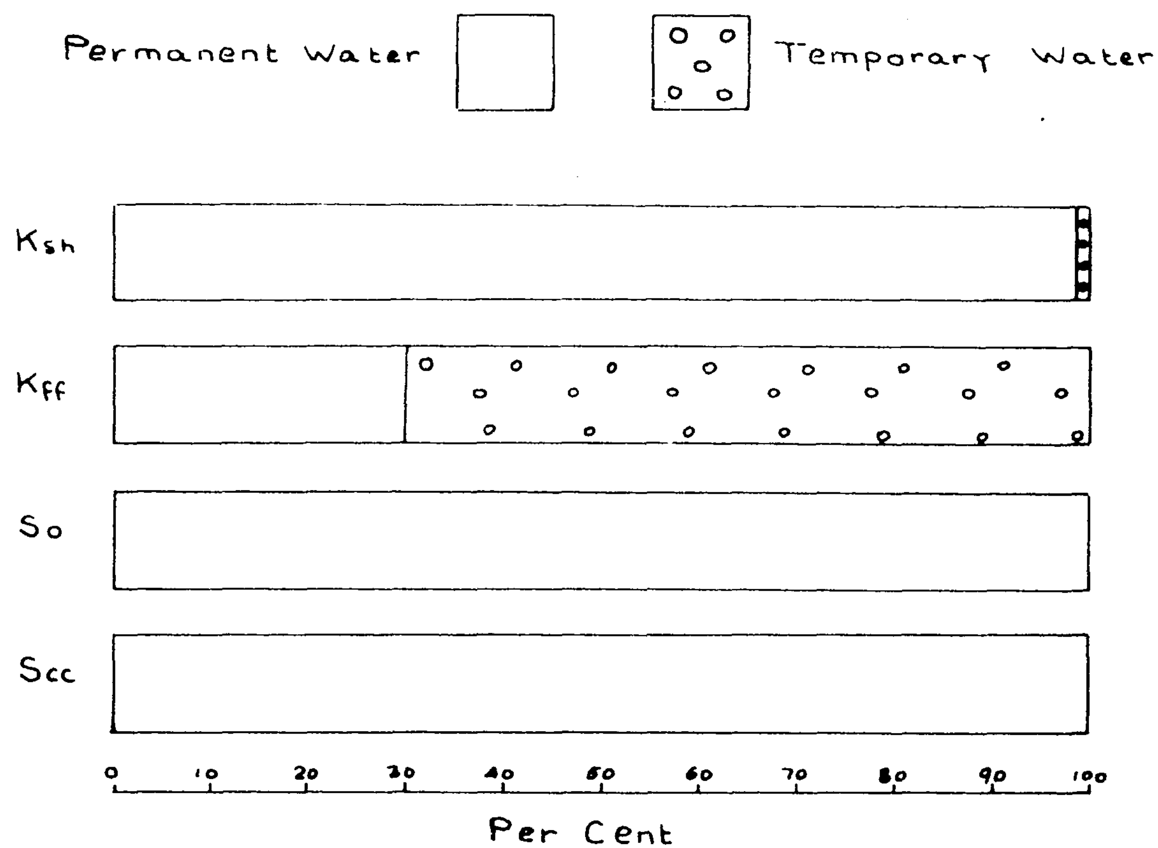

Shallow Creek (Spring - Fed)
Ditch
Artificial Pond
Lake
Flooded Field
Rivers and Large Creeks
Flood Plain
Slough
Mud - Hole
Ksh
Kff
So
Scc
0
10
20
30
40
50
60
70
80
90
100
Per Cent

Figure 2

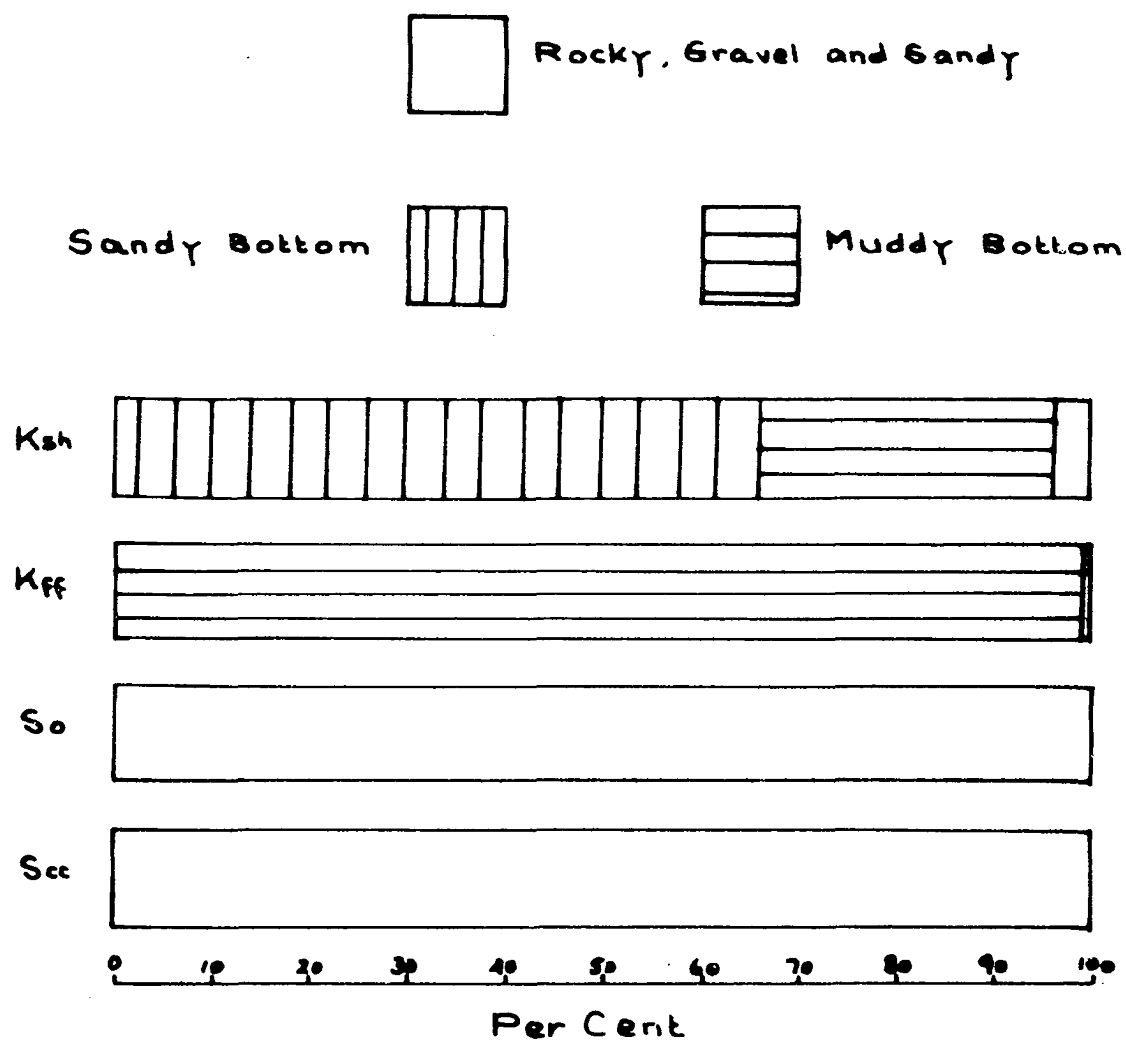
A comparison of the percentage of capture from permanent and temporary water habitats for four species of kinosternid turtles in Oklahoma, 1956-1959.



Permanent Water
Temporary Water
Ksh
Kff
So
Scc
0
10
20
30
40
50
60
70
80
90
100
Per Cent

Figure 3

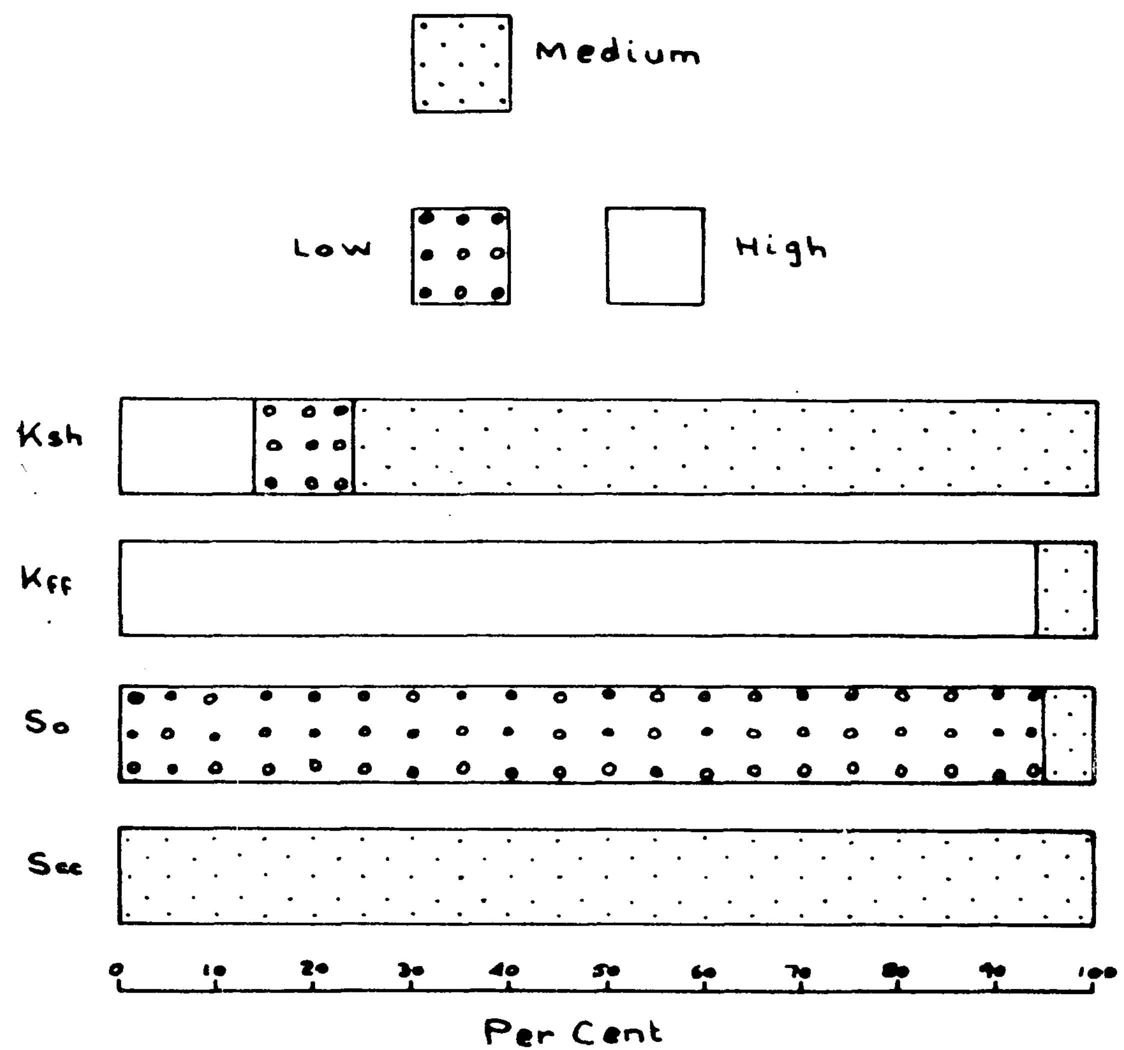
A comparison of the percentage of captures from different types of bottom of aquatic habitats for four species of kinosternid turtles in Oklahoma, 1956-1959.



Rocky, Gravel and Sandy
Sandy Bottom
Muddy Bottom
Ksh
Kff
So
Scc
0
10
20
30
40
50
60
70
80
90
100
Per Cent

Figure 4

A comparison of the percentage of captures from water of different turbidity of aquatic habitats for four species of kinosternid turtles in Oklahoma, 1956-1959.



Medium
Low
High
Ksh
Kff
So
Sec
0
10
20
30
40
50
60
70
80
90
100
Per Cent

Figure 5

A comparison of the percentage of capture from running and standing aquatic habitats for four species of kinosternid turtles in Oklahoma, 1956-1959.

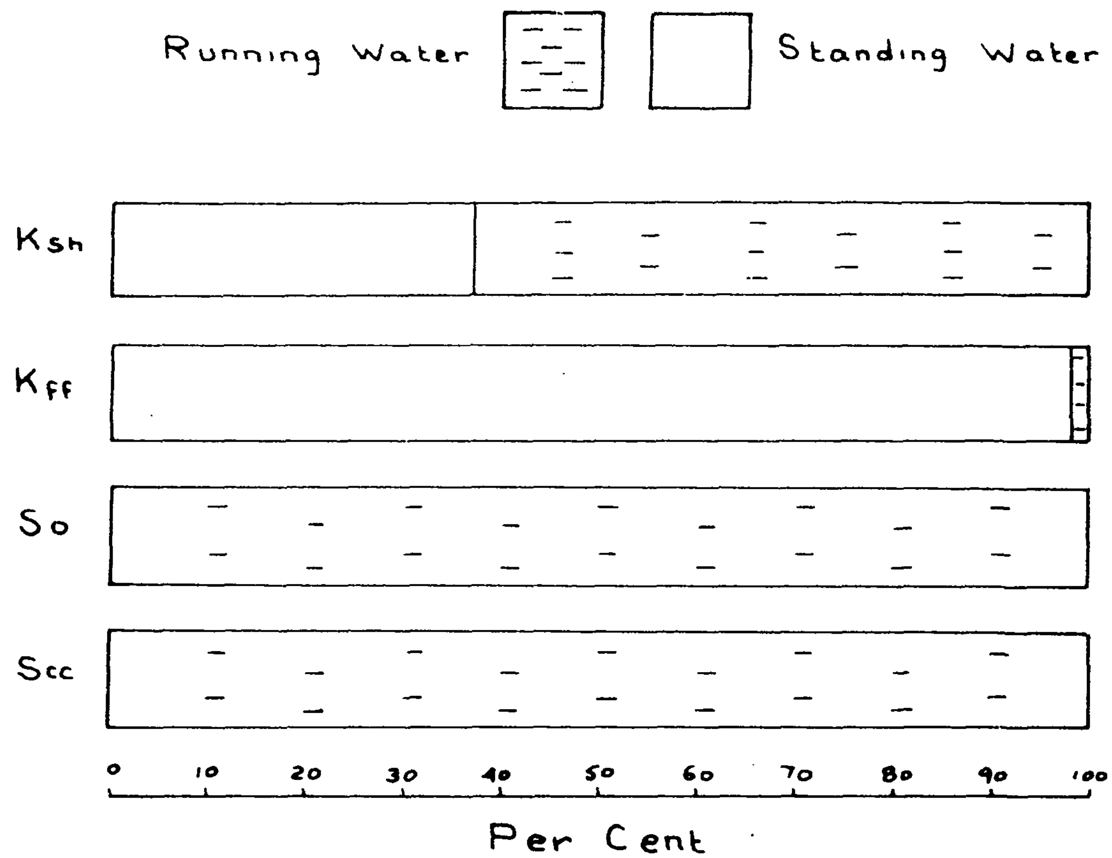
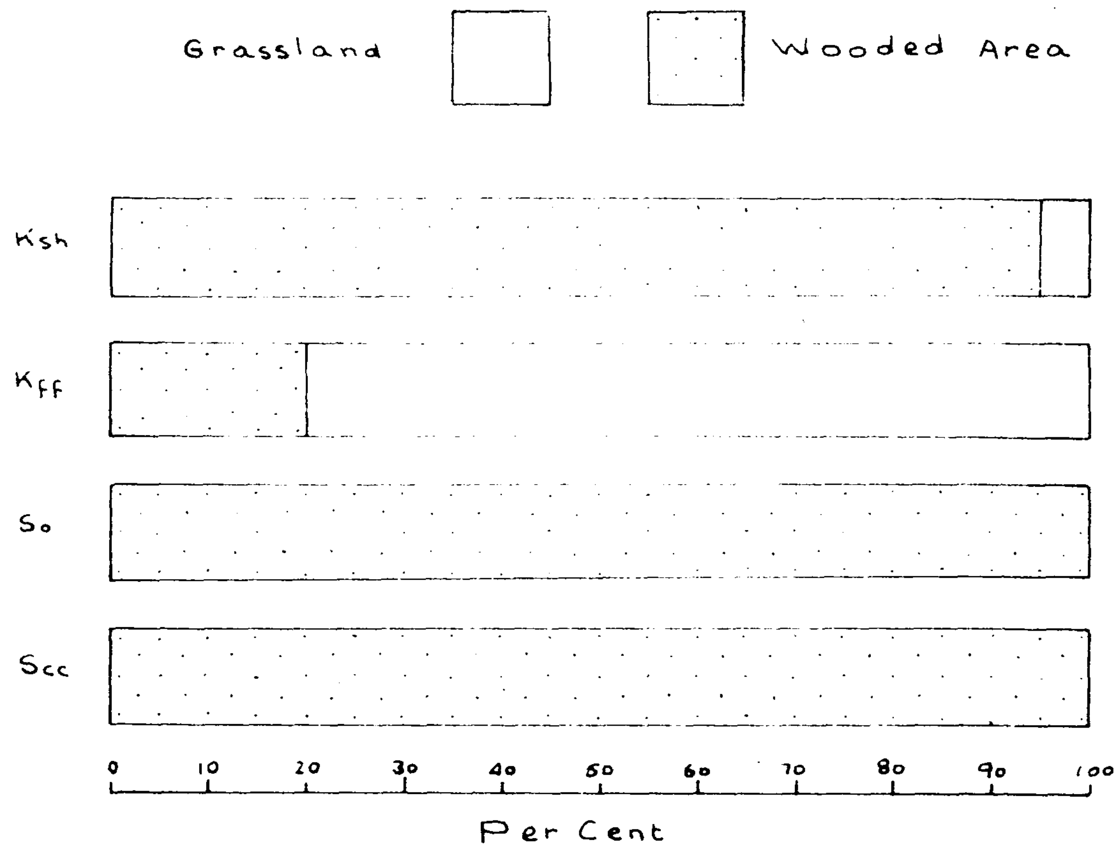

Running Water
Standing Water
Ksh
Kff
So
Scc
0
10
20
30
40
50
60
70
80
90
100
Per Cent

Figure 6

A comparison of the percentage of captures from different vegetational associations for four species of kinosternid turtles in Oklahoma, 1956-1959.



Grassland
Wooded Area
Ksh
Kff
So
Scc
0
10
20
30
40
50
60
70
80
90
100
Per Cent

TABLE 1.--A comparison of the percentage of the four species associated with the light or dark side and with the type of bottom

Species	Light side	Dark side	Gravel and rock side	Sand and mud side
Kinosternon flavescens flavescens	20%	80%	10%	90%
Kinosternon subrubrum hippocrepis	13%	87%	30%	70%
Sternothaerus odoratus	10%	90%	80%	20%
Sternothaerus carinatus carinatus	10%	90%	100%	--

CHAPTER III

TEMPERATURE

Recent investigations have shown that some reptiles can regulate their body temperatures through behavioral thermoregulation.

The cloacal temperatures of the turtles on which this study was based were recorded both in the field and in the laboratory. The thermometer bulb was inserted into the cloaca and read within ten seconds after capture. Water temperature was recorded at the exact point of capture and air temperature was taken three feet above this point.

The number of cloacal temperatures taken in the field were: *K. s. hippocrepis* - 257, *K. f. flavescens* - 180, *S. odoratus* - 253, and *S. c. carinatus* - 80. When the cloacal temperatures were plotted against the water temperatures, a straight line relationship was obtained (figs. 7-10) which indicated a close relationship between the two. The cloacal temperatures varied less than 1 degree above or below the water temperature in 97 percent of S. c. carinatus, 90 percent of K. s. hippocrepis, 99 percent of K. f. flavescens, and 94 percent of S. odoratus. The rest varied between 1 and 2 degrees above or below the water temperatures.

The difference of means between the cloacal and the environmental temperatures throughout the seasons was found to be very minute (table 2).

In the laboratory, the turtles of the four species were exposed to different water temperatures. These experiments were conducted in a concrete tank or in a glass aquarium both of which were filled with just enough water to cover the bodies of the turtles. The cloacal temperatures were taken after the turtles had been in the water 15 to 30 minutes.

The laboratory temperature data indicated that the means for the cloacal temperatures were similar to those for the water temperatures (figs. 11-12). The difference between the cloacal and the water temperatures was less than 1 degree for all records, giving a straight line relationship. Even when the turtles were exposed to water temperatures as high as 42°C or as low as 0.1°C, they soon reached a thermal equilibrium with that of the water.

The laboratory and field data thus indicated that there was very little behavioral thermoregulation in the four species. However, during the spring, occasional basking in the field was observed in each species. This is possibly explained by: (1) the turtles were close to their voluntary minimum in the spring and thus behavioral thermoregulation was practiced; (2) these species did not show any photophobic tendencies during this season. During the summer basking was rare and photophobic tendencies were very strong.

The temperature fluctuations in the aquatic habitat varied less abruptly from one spot to another than corresponding terrestrial situations. It was probably for this reason that these species showed little behavioral thermoregulation. However, behavioral thermoregulation is probably beneficial in the terrestrial reptiles which face drastic changes in temperatures from one locality to another.

Cowles and Bogert (1944) have indicated that each species has a certain body temperature range, the normal activity range, over which the animal is active. Carpenter (1956) called this range the thermo-activity range (TAR). All plotted cloacal temperatures were taken on active turtles and thus fall within the thermo-activity range of each respective species (fig. 13). Since it is probable that the body temperature is a function of the immediate environmental temperature in the four species, water temperatures were recorded for all of the sight observations. These records were used to help predict the thermo-activity range where other records were scant, especially for S. c. carinatus. The observed thermo-activity range for K. s. hippocrepis, K. f. flavescens, S. odoratus, and S. c. carinatus were 16°C to 36°C, 18°C to 32°C, 10°C to 34°C, and 14°C to 34°C respectively. S. odoratus and K. s. hippocrepis had the broadest thermo-activity range while S. c. carinatus and K. f. flavescens were more restricted in that respect.

The preferred body temperature (the mean body temperature, Cowles and Bogert [1944]), was obtained for the four species for each season (table 2). The preferred body temperature of K. s. hippocrepis (23.65°C), K. f. flavescens (25.06°C), and S. odoratus (24.14°C) showed a close similarity to one another during the summer, whereas S. c. carinatus (33.29°C) showed a higher preferred body temperature than the other three. That most S. c. carinatus collections came from one area where the water temperature remained high throughout the summer probably accounted for this.

In the laboratory the thermo-activity range of each species was determined by observing the feeding habits, sexual behavior, and wandering movements at different cloacal temperatures. The minimum and maximum body temperatures at which K. s. hippocrepis, K. f. flavescens, S. odoratus, and S. c. carinatus would accept food were: 13°C and 38°C; 16°C and 38°C; 13°C and 35°C; and 16°C and 34°C respectively. The body temperature range, over which sexual behavior was observed was between 20°C and 30°C in each species. The thermo-activity range for S. odoratus and S. c. carinatus in the laboratory was almost the same as that for the field, but K. s. hippocrepis and K. f. flavescens in the laboratory showed more tolerance for high temperatures and thus a broader thermo-activity range than that for the field.

In captivity the four species showed greater activity at water temperatures between 21°C and 26°C.

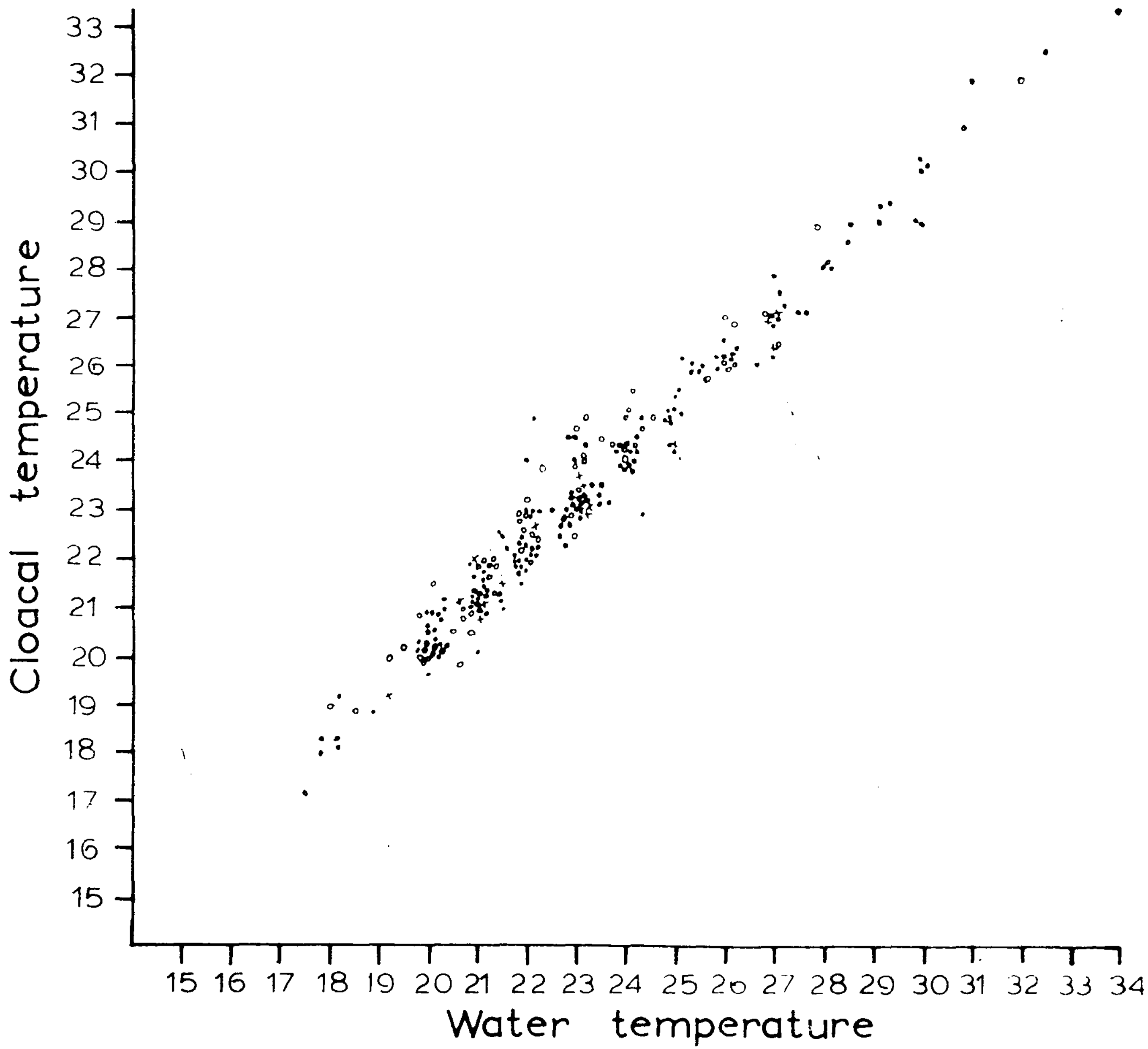
The maximum and minimum lethal temperatures for K. s. hippocrepis, K. f. flavescens, S. odoratus, and S. c. carinatus were 0°C and 44°C, 0°C and 44°C, 0°C and 42.8°C, and 0°C and 42.10°C respectively (table 3). At these temperatures the turtles became motionless with eyes closed, and within a short time died. At a few degrees below the maximum lethal temperature, the turtles became excessively active, breathing was very fast, and "involuntary defecation" was noticed. At a few degrees above $0^{o}C$ the turtles were motionless with their eyes closed (table 3). However, when the water approached their minimum voluntary temperature their eyes opened and they showed some very sluggish movements.

Several individuals of the four species were kept in water in a cold box 35 days during which time the cloacal temperatures varied between $0.1^{o}C$ and $0.4^{o}C$ without causing any permanent injury to the turtles. Therefore it appeared that mortality during hibernation is rare in nature, especially when the turtles were several inches beneath the ground or water.

The intrageneric comparison showed that the field and the laboratory temperature records were similar for the maximum voluntary temperatures, but this did not hold for the minimum. In the laboratory the intergeneric comparison showed that Kinosternon had more tolerance for high temperature, while in the field they all showed the same tolerance for high temperature. In the field Sternothaerus had more tolerance for low temperature than Kinosternon.

Figure 7

The relationship between water temperature and cloacal temperature for Kinosternid subrubrum hippocrepis in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



Cloacal temperature
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Water temperature

Figure 8

The relationship between water temperature and cloacal temperature for Kinosternid flavescens flavescens in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.

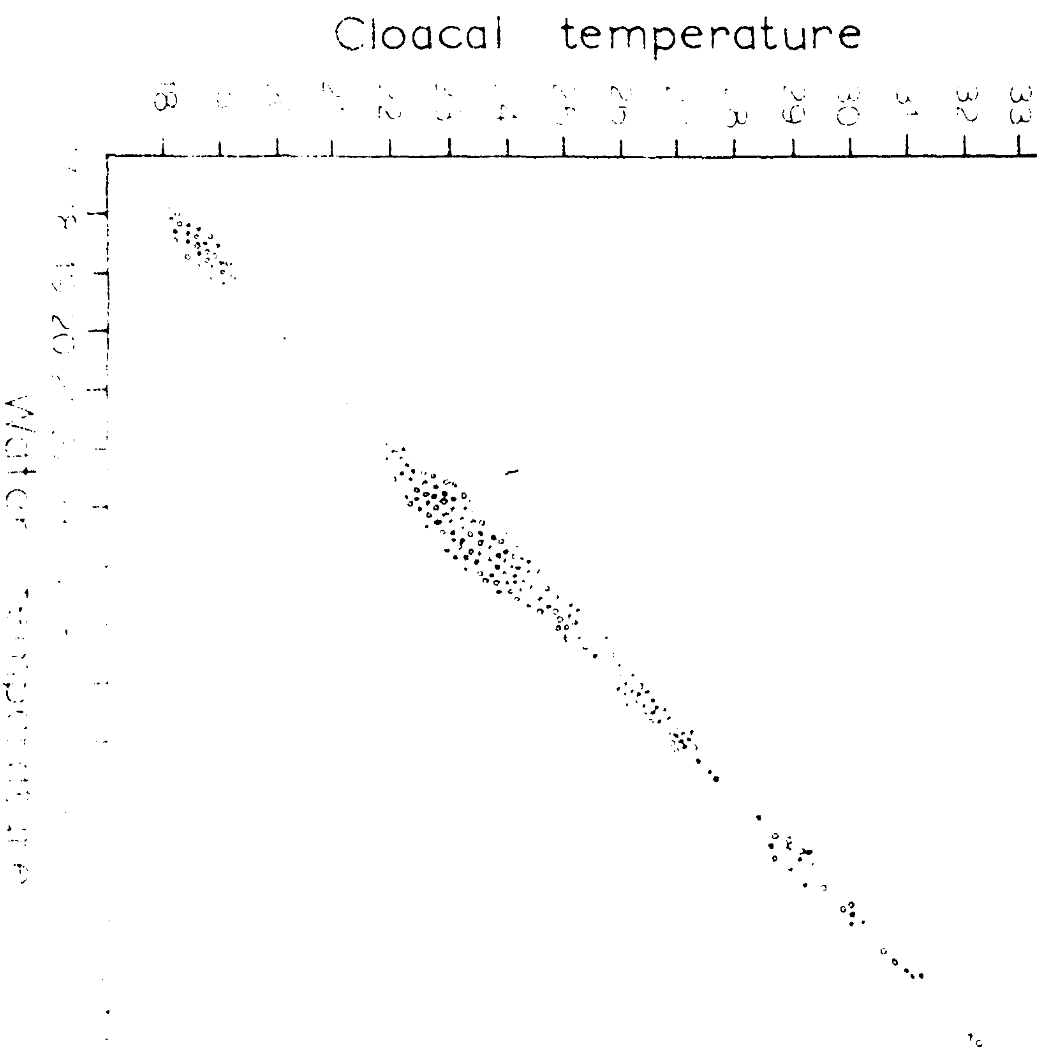
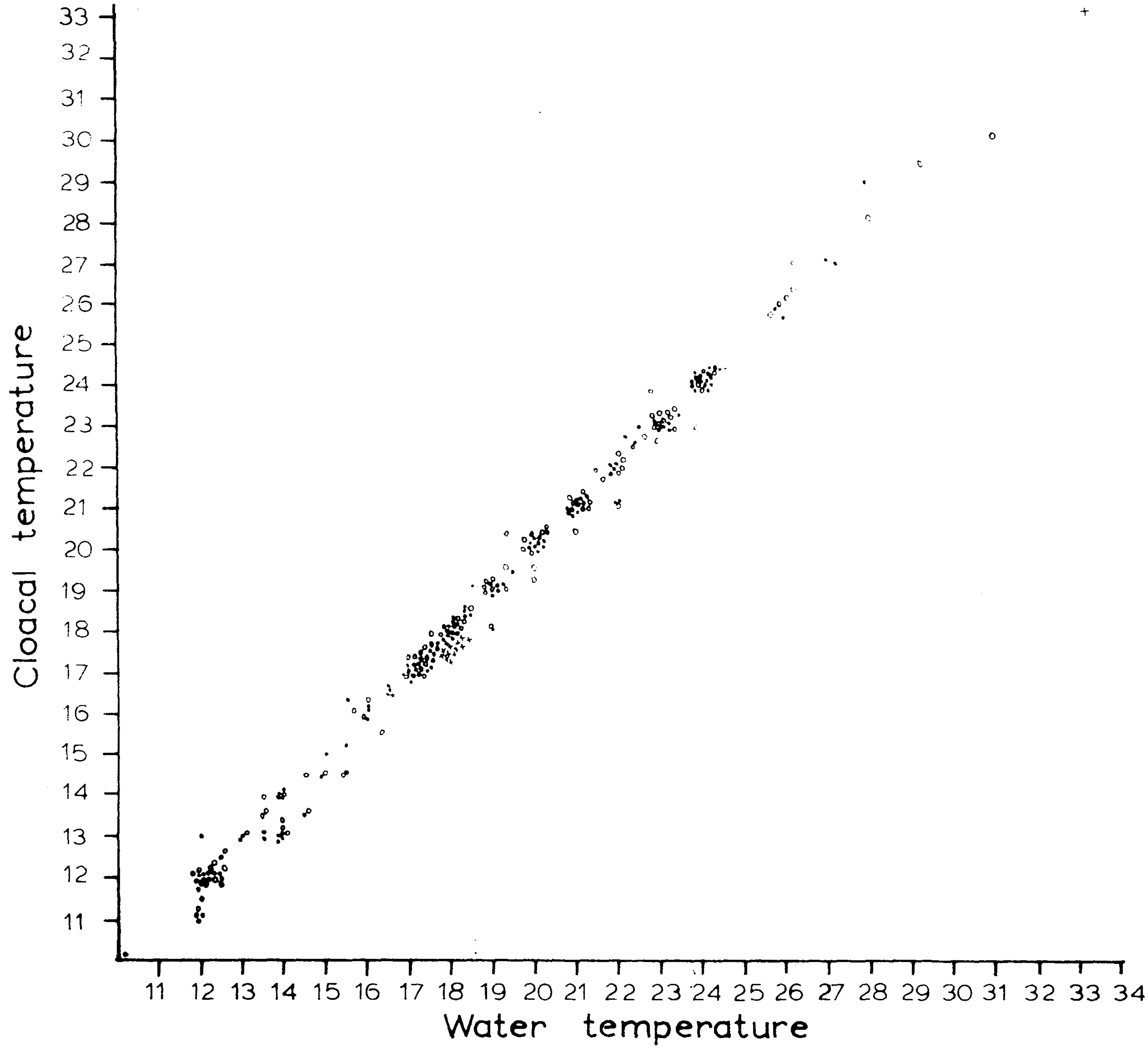

Cloacal temperature

Figure 9

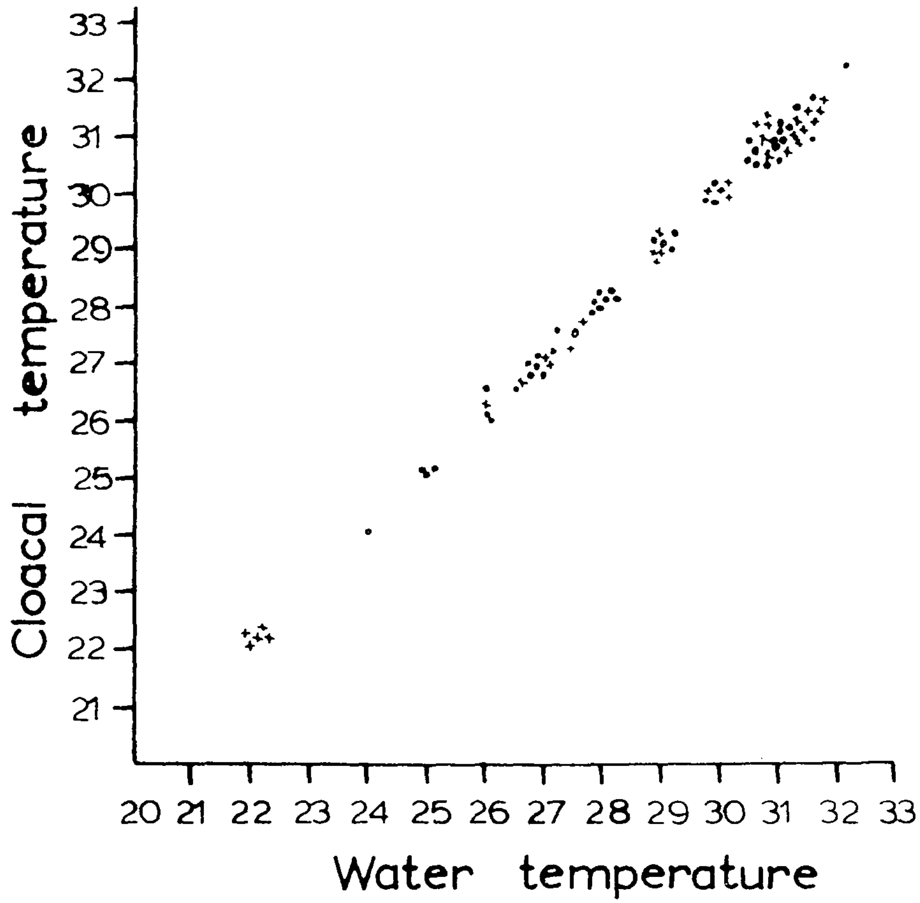
The relationship between water temperature and cloacal temperature for *Sternothaerus odoratus* in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



Cloacal temperature
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Water temperature

Figure 10

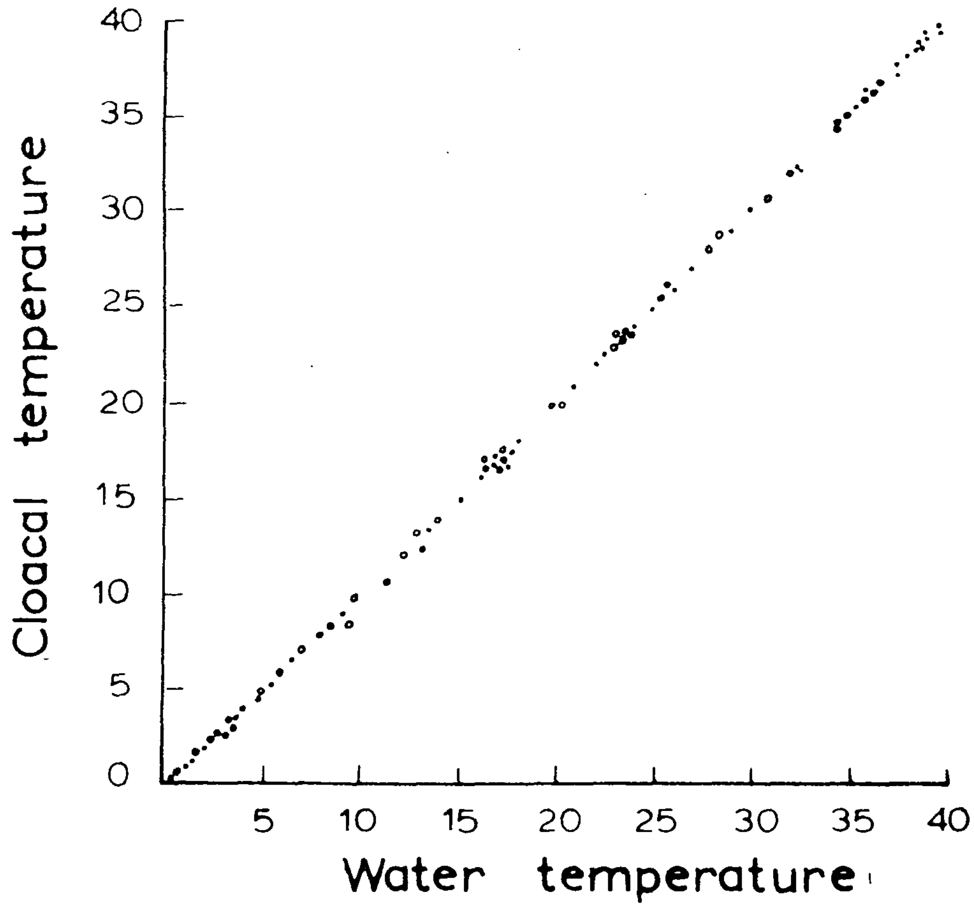
The relationship between water temperature and cloacal temperature for *Sternothaerus carinatus carinatus* in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



Cloacal temperature
33
32
31
30
29
28
27
26
25
24
23
22
21
20 21 22 23 24 25 26 27 28 29 30 31 32 33
Water temperature

Figure 11

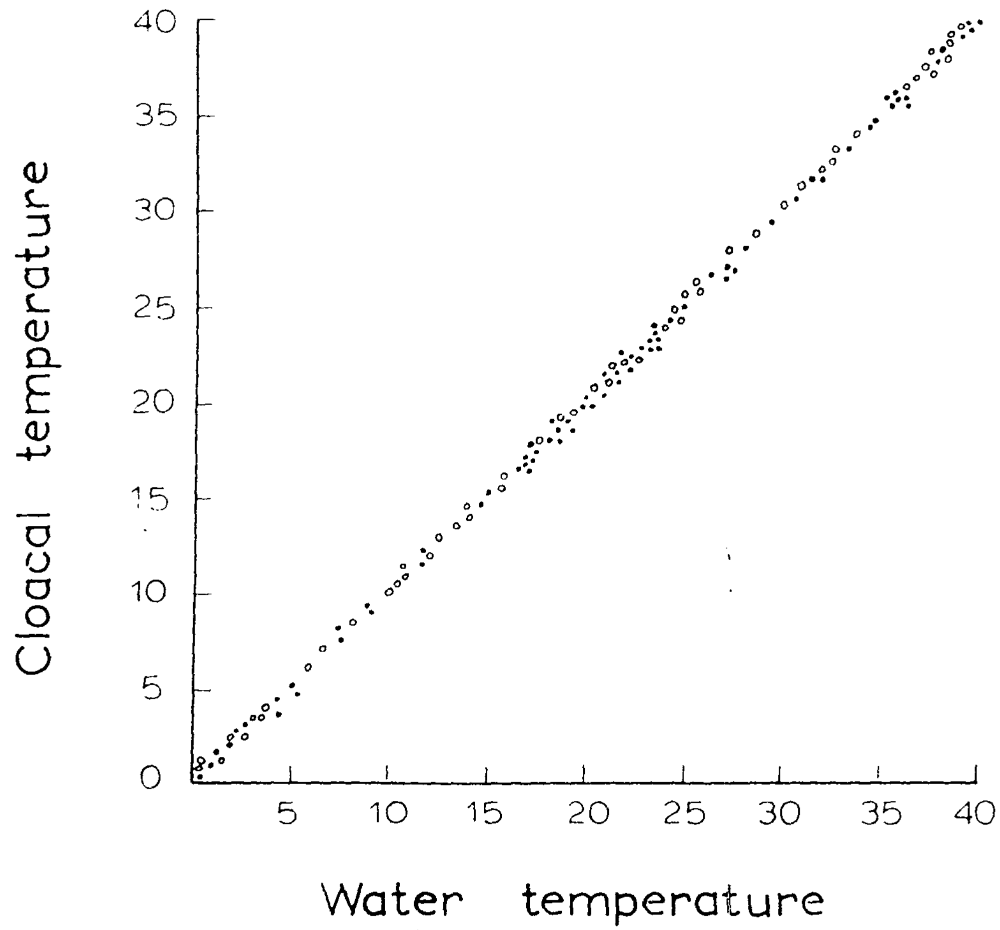
The relationship between water and cloacal temperatures for <u>Kinosternon</u> under controlled laboratory conditions. Each point represents a mean for five observations with a range of less than 1°C. Dots = males; circles = females.



Cloacal temperature
Water temperature
0
5
10
15
20
25
30
35
40

Figure 12

The relationship between water and cloacal temperatures for Sternothaerus under controlled laboratory conditions. Each point represents a mean for five observations with a range of less than 1^{o}C. Dots = males; circles = females.



40
35
30
25
20
15
10
5
0
5 10 15 20 25 30 35 40
Cloacal temperature
Water temperature

Figure 13

The thermo-activity range of four species of Kinosternid turtles in Oklahoma, 1956-1959. The broken lines represent the water temperatures during sight observations.

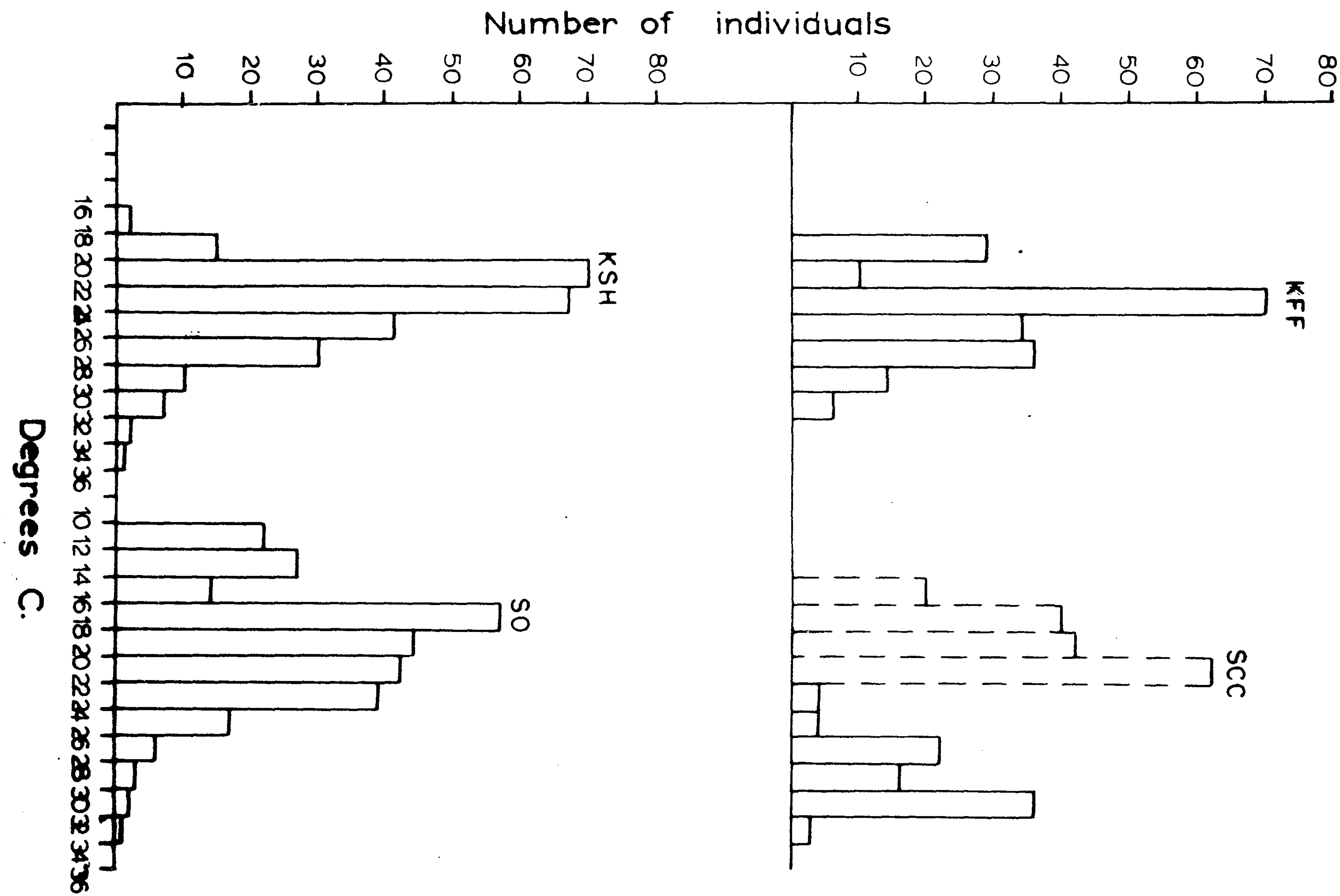

Number of individuals
10 20 30 40 50 60 70 80
10 20 30 40 50 60 70 80
KSH
KFF
SO
SCC
16 18 20 22 24 26 28 30 32 34 36
10 12 14 16 18 20 22 24 26 28 30 32 34 36
Degrees C.

TABLE 2.--Cloacal temperatures and water temperatures at sites of capture for four species of kinosternid turtles in Oklahoma, 1956 to 1959

<u>Kinosternon</u> <u>subrubrum</u> <u>hippocrepis</u>

Month	Sex	Number of Records	Cloacal mean	Environmental mean	Difference of mean
June-August	Male	78	23.54 ± 3.17 (15.30-32.00)	23.18 ± 3.15 (15.30-30.8)	+0.36
	Female	114	23.82 ± 3.24 (17.30-31.9)	23.69 ± 3.40 (17.50-31.00)	+0.13
	Juvenile	13	23.60 ± 3.10 (18.4-28)	23.58 ± 3.28 (18.3-28.2)	+0.2
Sept.-Nov.	Male	15	22.14 ± 2.26 (18.90-27)	21.68 ± 2.24 (17-26.90)	+0.46
	Female	17	22.82 ± 1.19 (20.50-24.8)	22.60 ± 1.26 (20-24.90)	+0.22
	Juvenile	6	22.56 ± 1.22 (21-23.6)	22.50 ± 1.16 (21-23.3)	+0.6
Dec.-Feb.	Male	7	6.20 ± 237 (3.1-8.80)	6.27 ± 260 (3.3-8.80)	-0.7
	Female	7	5.74 ± 227 (3.3-9.6)	5.82 ± 230 (3.3-9.6)	-0.8

TABLE 2.--Continued

			Sternothaerus odoratus		
Month	Sex	Number of Records	Cloacal mean	Environmental mean	Difference of mean
June-August	Male	48	22.23 ± 2.29 (19-20.30)	22.22 ± 2.61 (19.00-29.30)	+0.01
	Female	46	22.50 ± 2.38 (18.20-28.80)	22.45 ± 2.36 (18.00-28.00)	+0.05
	Juvenile	5	27.70 ± 4.66 (24.30-33.90)	27.12 ± 4.16 (24.30-33.90)	+0.58
Sept.-Nov.	Male	25	18.10 ± 3.43 (12.50-26.30)	18.16 ± 3.41 (12.50-26.30)	-0.06
	Female	23	19.21 ± 2.71 (15-26.70)	19.26 ± 2.83 (15.00-27.20)	- .05
	Juvenile	13	17.63 ± 0.10 (17.60-18.00)	17.63 ± 0.1 (17.60-18.00)	0.00
Dec.-Feb.	Male	29	14.26 ± 2.69 (9.70-17.80)	14.53 ± 2.51 (9.70-17.80)	- .27
	Female	25	14.57 ± 2.66 (10.2-18.4)	14.87 ± 2.61 (10-19.00)	- .30
March-May	Male	19	16.11 ± 3.33 (11.8-22.90)	16.10 ± 3.27 (11.80-22.90)	+0.01
	Female	20	14.89 ± 2.50 (11.8-19.00)	15.02 ± 2.38 (11.8-19)	- .13

TABLE 2.--Continued

Sternothaerus carinatus carinatus

Month	Sex	Number of Records	Cloacal mean	Environmental mean	Difference of mean
June-August	Male	17	29.21 ± 2.92 (24-33.8)	29.11 ± 291 (24-33.8)	+ .10
	Female	24	30.11 ± 1.76 (28-32.2)	30.22 ± 1.58 (28-32.2)	- .11
	Juvenile	7	30.54 ± 1.35 (26.50-31.2)	30.33 ± 1.27 (26.50-31.2)	+ .21
Sept.-Nov.	Male	10	28.81 ± 5.42 (26.5-31.10)	28.74 ± 6.49 (26-31)	+0.07
	Female	15	28.16 ± 1.43 (26-31.20)	28.10 ± 1.41 (26-31)	+ .06
	Juvenile	7	27.10 ± .938 (26.20-28.90)	27.04 ± .959 (26-28.8)	+ .06

TABLE 2.--Continued

Kinosternon flavescens flavescens

Month	Sex	Number of Records	Cloacal mean	Environmental mean	Difference of mean
June-August	Male	45	24.60 ± 2.52 (21-30)	24.57 ± 2.48 (21-30)	+ .3
	Female	48	25.36 ± 2.61 (22.3-31.2)	25.32 ± 2.59 (22.3-31.10)	+ .4
	Juvenile	21	25.22 ± 1.44 (23.30-38.8)	25.19 ± 1.46 (23.2-28.8)	+ .3
March-May	Male	18	19.99 ± 1.25 (18.8-24)	19.99 ± 2.00 (18.8-24)	0
	Female	27	20.84 ± 2.76 (18.8-28.4)	20.84 ± 2.76 (18.8-28.4)	0
	Juvenile	21	22.17 ± 1.77 (18.8-24.3)	22.19 ± 1.76 (18.8-24.3)	- .2

TABLE 3.--Behavioral responses of four species of kinosternid turtles at different temperatures

Kinosternon subrubrum		*Kinosternon flavescens*	
Body temp. in °C	Remarks	Body temp. in °C	Remarks
0°C	min. lethal	0°C	min. lethal
0.1°C to 2°C	eyes-closed turtle motionless	0.1°C to 2°C	eyes-closed turtle motionless
2.1°C to 13°C	eyes-opened animal very sluggish slow movements	2.1°C to 16°C	eyes-opened animal very sluggish slow movements
13°C to 38°C	Thermal Feeding Range (TFR)	16.1°C to 38°C	Thermal Feeding Range (TFR)
38.1°C to 43.9°C	Very active breathing fast involuntary defecation	38.1°C to 43.9°C	Very active breathing fast involuntary defecation
44°C	max. lethal	44°C	max. lethal

TABLE 3.--Continued

Sternothaerus odoratus		*Sternothaerus carinatus*	
Body temp. in °C	Remarks	Body temp. in °C	Remarks
0°C	min. lethal	0°C	min. lethal
0.1°C to 2°C	eyes-closed turtle motionless	0.1°C to 2°C	eyes-closed turtle motionless
2.1°C to 13°C	eyes-opened animal very sluggish slow movements	2.1°C to 16°C	eyes-opened animal very sluggish slow movements
13.1°C to 35°C	Thermal Feeding Range (TFR)	16.1°C to 34°C	Thermal Feeding Range (TFR)
35.1°C to 42.7°C	Very active breathing very fast, involuntary defecation	34.1°C to 42°C	Very active breathing very fast, involuntary defecation
42.8°C	max. lethal	42.10°C	max. lethal

CHAPTER IV

DIEL CYCLE

The diel cycle of each of the four species studied can be divided into two periods: the resting period during which the animal was inactive, and the activity period which was mainly dominated by feeding, occasional basking, sexual behavior, and wandering movements. The diel activities varied from season to season and from day to day depending on the climatic and weather conditions.

Light intensity and temperature were the main environmental factors affecting the diel cycle. During the summer most of the habitats visited usually had water temperatures ranging within the thermo-activity range of the four species; however, the degree of light intensity varied from time to time during the day. Since these turtles were photophobic during the summer, it was assumed that light intensity might be more critical than temperature in influencing the daily cycle of the four species. Trapping, fishing, hand collecting and sight records during the summer showed that the turtles were more active from shortly before to shortly after sundown than two or three hours earlier, even though the water temperature was the same or varied only a fraction of a degree. During cloudy and rainy days the turtles were active throughout the day, due to decreased light intensity. The lowering of the water temperature by inflowing rain waters during such days increased turtle activity. Almost all the turtles of the four species which were caught during the summer in late morning and early afternoon were taken during cloudy and rainy days (figs. 14-17) or were caught in well shaded areas where light intensity was very low. Sporadic activities of the four species were observed during almost every hour of the night.

During late fall and early spring when the four species were active, their body temperature usually varied between $1^{o}C$ and $4^{o}C$ above their minimum voluntary temperature. During these months the daily activity periods of the four species were from late morning to sundown during which time the water temperature was at its highest. Occasional basking was observed in the four species during these hours.

There appeared to be no correlation between the cloacal temperatures of the four species and the periods of activity throughout the seasonal and diel cycles, indicating no seasonal or daily rhythm in the body temperature.

From June through August the diel cycle of K. s. hippocrepis in Cowan Creek showed two periods of activity. The morning period was between 4:00 A.M. and 9:00 A.M. with a peak between 5:20 A.M. and 8:00 A.M., while the evening period was between 4:40 P.M. and 10:00 P.M. with a peak from 7:00 P.M. to 8:00 P.M. (fig. 14).

On August 15, 1956, a female K. s. hippocrepis from Cowan Creek emerged from a sand bar near the edge of the Creek, at 6:15 A.M. She first moved 100 feet north and stopped and fed for 20 minutes in a small depression along the side of the creek. At 7: A.M. she started south and after moving 70 feet, met a male at 7:16 A.M. Without observed courtship the male copulated with her immediately. The copulation lasted 15 minutes. When they separated, the male moved north and was lost from sight, while the female traveled 15 feet south and started to feed again on algae along the edge of the creek. Ten minutes later she moved 5 feet south and burrowed into a sandy bar along the edge of the creek 10 feet north from the spot from which she first emerged 93 minutes previously.

The diel cycle of S. odoratus in Honey Creek (fig.

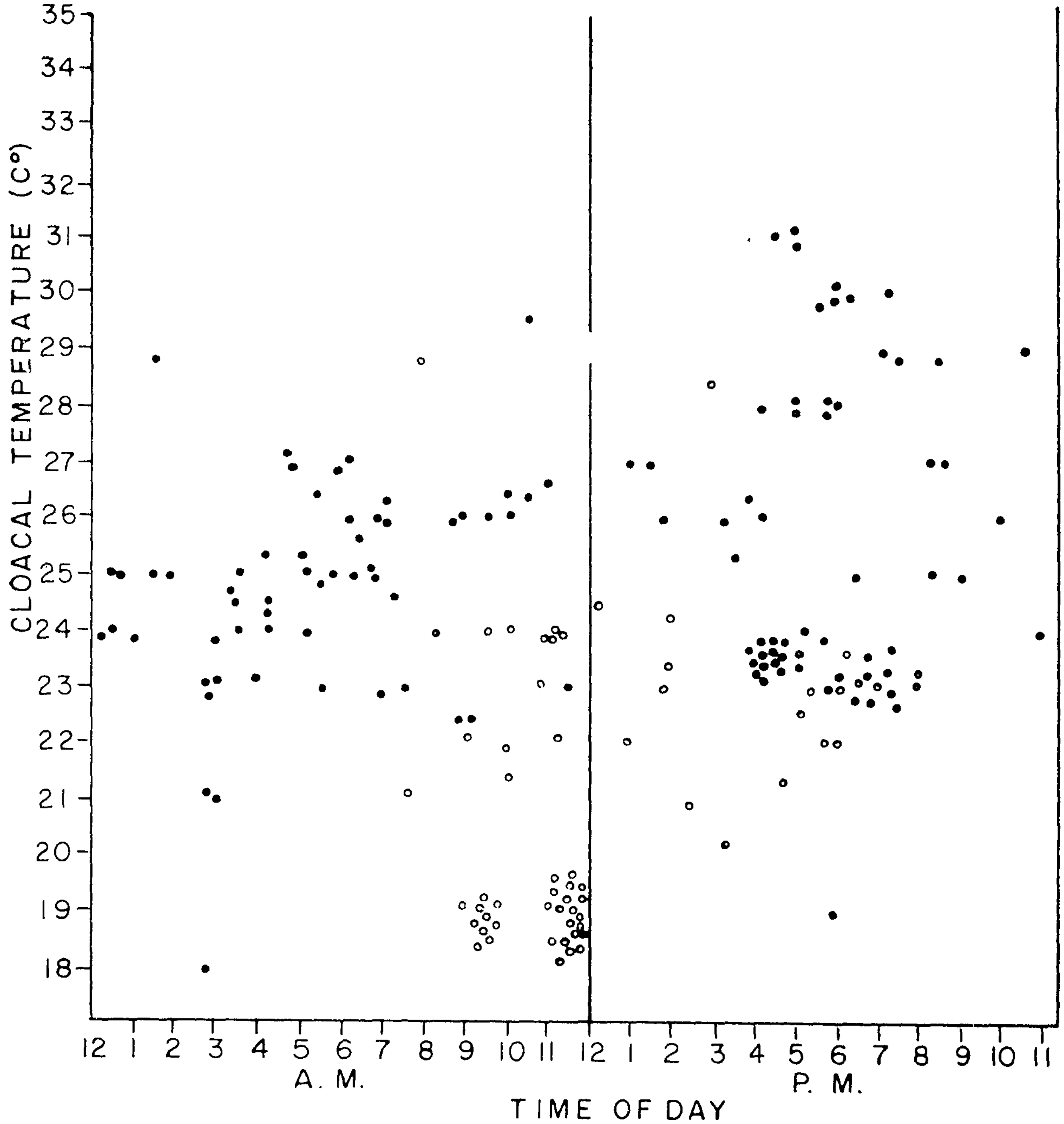
16) also showed morning and evening activity from May to August. The morning activity was from 4:00 A.M. to 10:20 A.M. while the evening activity was from 5:40 P.M. to 9:00 P.M. From September to April, most of the activity was between 10:00 A.M. and 4:00 P.M.

K. f. flavescens which were taken from Berry's Pond, Donita's Pond and the Oliver Wildlife Preserve (fig. 15) were active between 9:00 A.M. and 8:00 P.M. during the months of April and May. During June and July, the diel cycle had two periods of activity. The morning period was between 12:00 midnight and 7:40 A.M., while the evening period was between 4:00 P.M. and 7:00 P.M. After July 15, the daily activity of this species gradually declined and by the early part of August, the species was inactive, probably in aestivation. However, during thundershowers, several individuals were seen active for a few hours.

From June to September *S. c. carinatus* observed in in the Mt. Fork River (fig. 14) showed two periods of activity. The morning period was from 3:00 A.M. to 10:00 A.M. while the evening period was between 4:40 P.M. and 11:00 P.M. Sight observations between October and early May indicated that its diel activity cycle was smilar to that of *S. odoratus*.

Figure 14

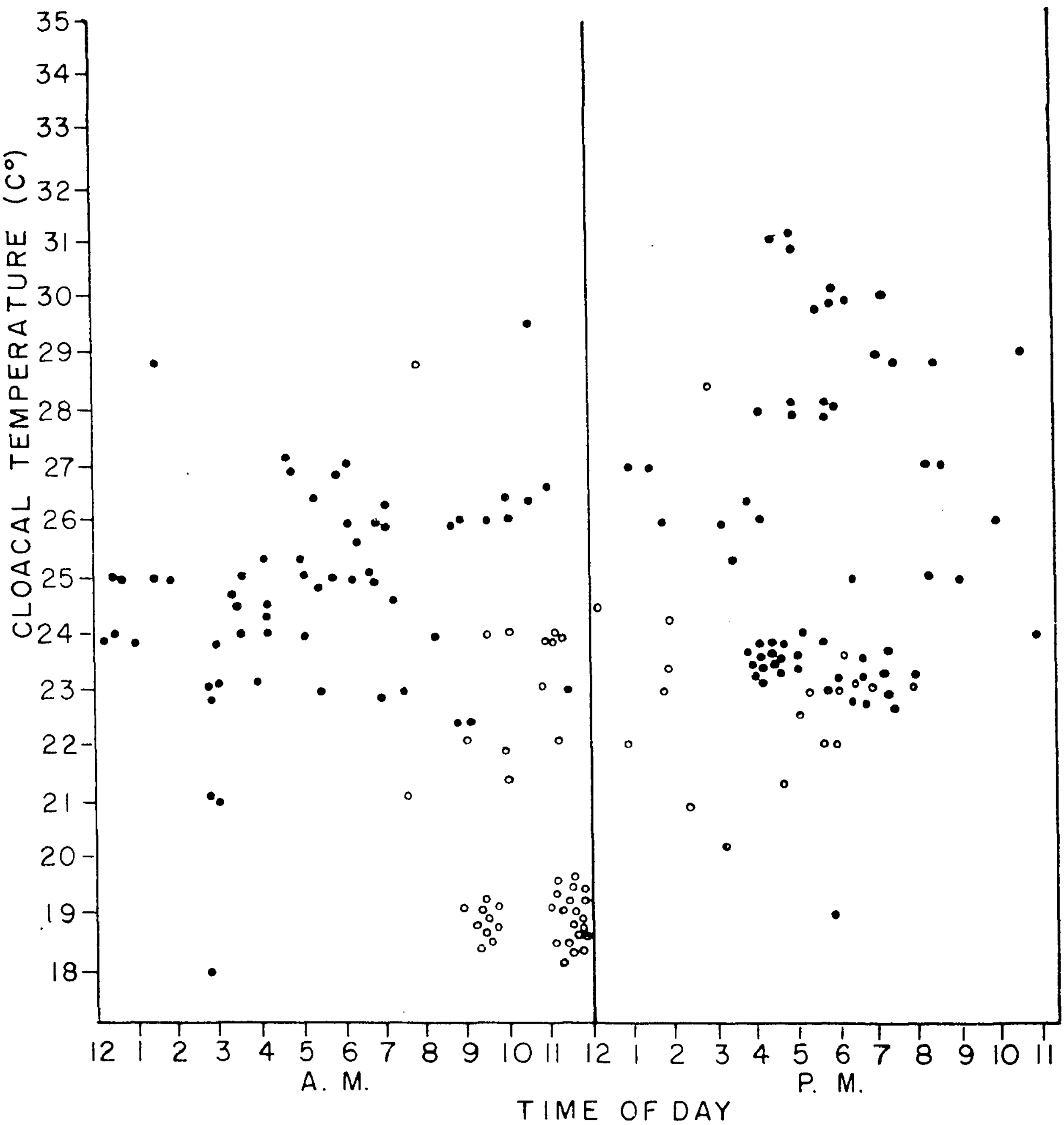
Cloacal temperatures of *Kinosternon subrubrum hippocrepis* relative to hour of capture. Dots = males; circles = females; crosses = juveniles.



CLOACAL TEMPERATURE (C°)
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11
A. M.
P. M.
TIME OF DAY

Figure 15

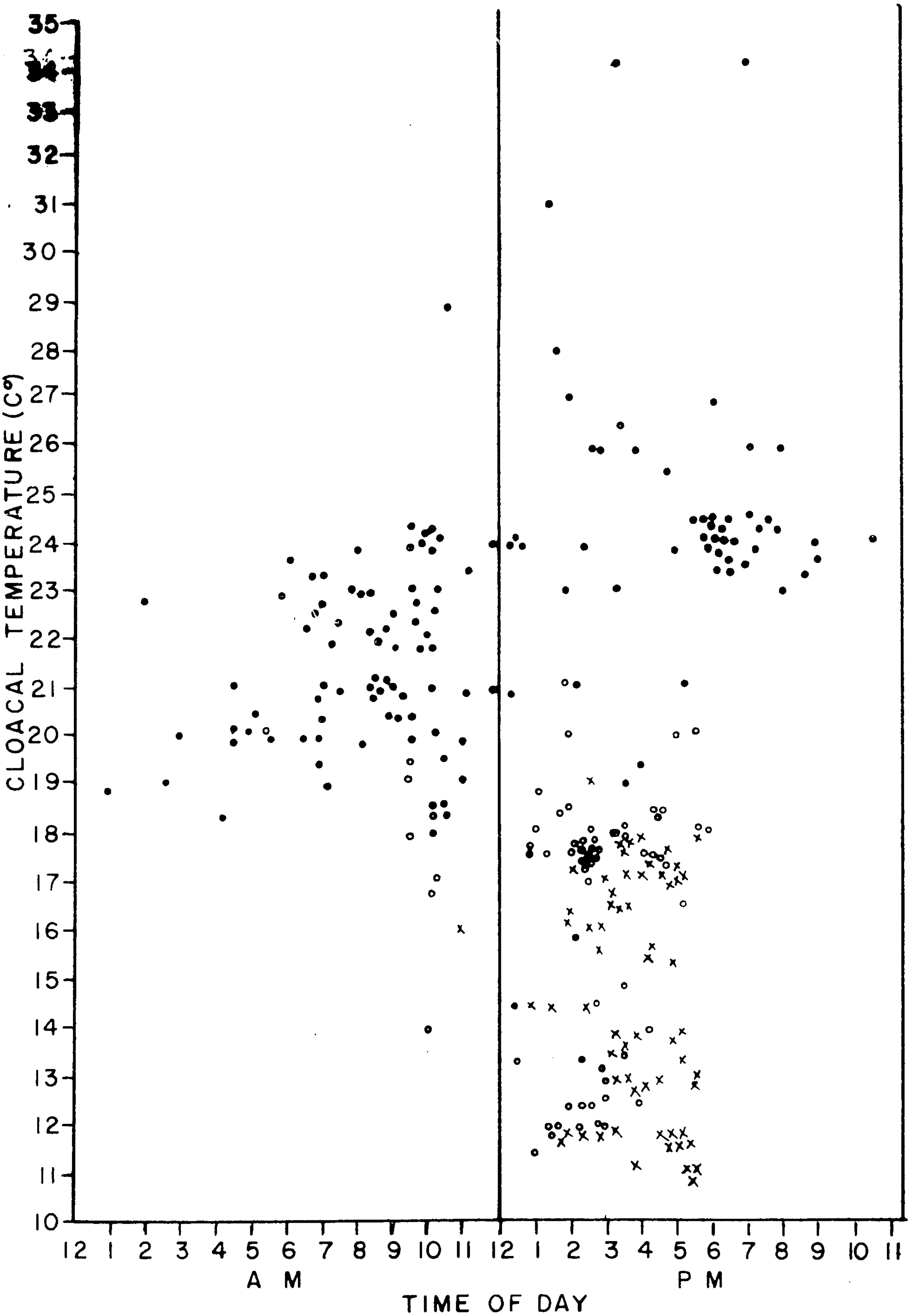
Cloacal temperatures of *Kinosternon flavescens flavescens* relative to hour of capture. Dots = males; circles = females.



CLOACAL TEMPERATURE (C°)
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11
A. M.
P. M.
TIME OF DAY

Figure 16

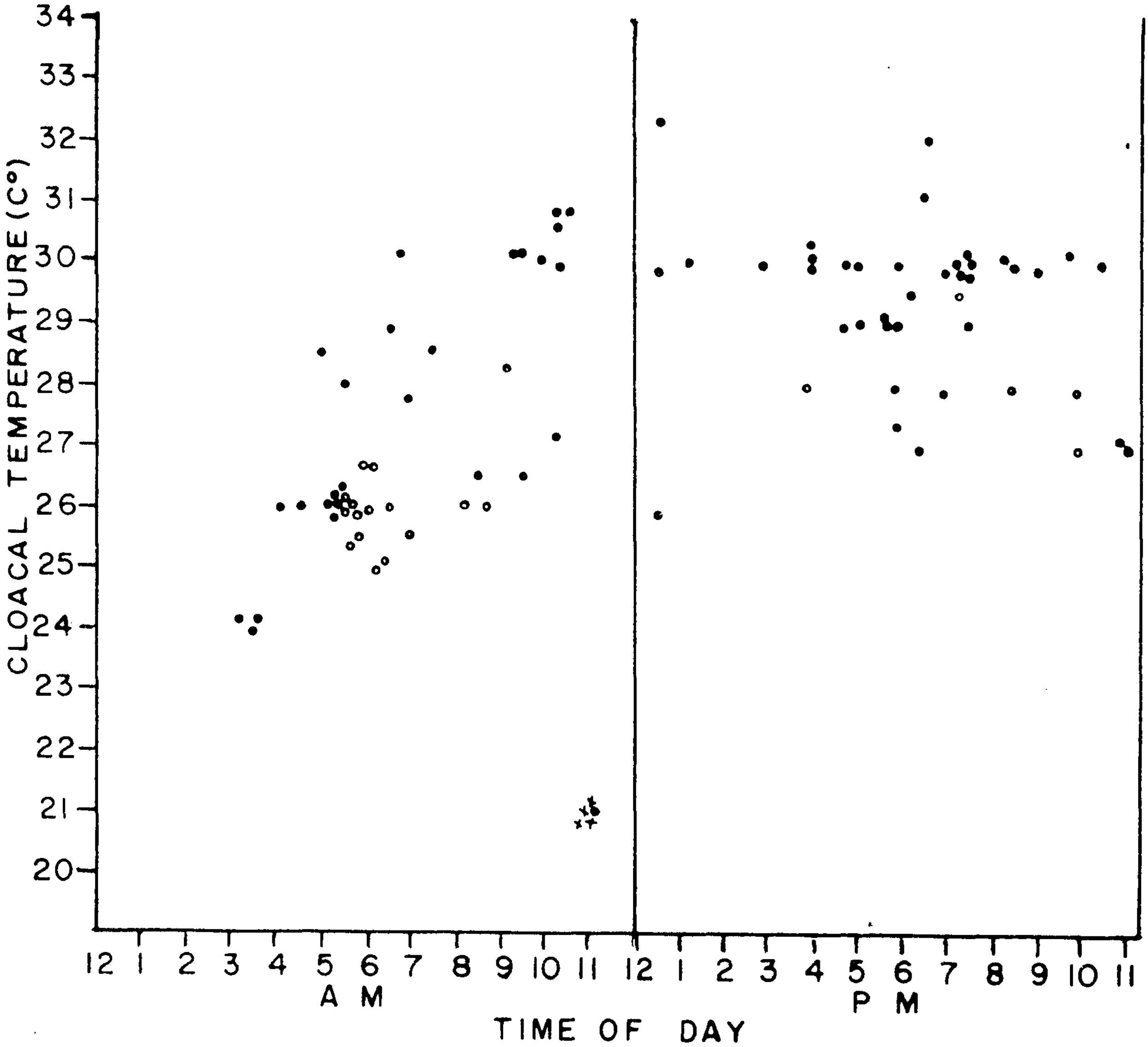
Cloacal temperatures of Sternothaerus odoratus relative to hour of capture. Dots = males; circles = females; crosses = juveniles.



CLOACAL TEMPERATURE (C°)
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11
A M
P M
TIME OF DAY

Figure 17

Cloacal temperatures of Sternothaerus carinatus carinatus relative to hour of capture. Dots = males; circles = females; crosses = juveniles.



CLOACAL TEMPERATURE (C°)
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11
A M
P M
TIME OF DAY

CHAPTER V

MOVEMENT

Studies of home range, activity range (as defined by Carpenter [1952]), and territoriality in animals have obtained special attention in recent years. Marking and recapture techniques have been used by many workers as a method of determining the patterns of movement in animals.

Several investigations have been conducted on movement and activity range of turtles. Schmidt (1916), Pearse (1923), Bogert (1937), Nichols (1939), Cagle (1939), Woodbury and Hardy (1948), Stickel (1950), Williams (1952), Breckenridge (1955), Carr and Caldwell (1956), Carr and Brovannoli (1947), and Sexton (1959) found that turtles exhibit limited movement.

In this problem, the points of original capture and recapture for each turtle were plotted on the specific area maps, from which maximum and minimum movement, direction of movement, and size of activity range were obtained (figs. 18-31).

In order to determine the movements of turtles for the entire year, the annual inactivity period was obtained by subtracting the activity period from 365 days. Thus the elapsed period between any successive captures was based on the annual number of activity days.

S. odoratus and S. c. carinatus were active most of the year with some sporadic inactivity during December, January, and February when the water temperature was below their thermo-activity range. The annual activity periods for S. odoratus and S. c. carinatus were estimated to be 330 days and 310 days respectively, in contrast to 265 days for K. s. hippocrepis, and 140 days for K. f. flavescens. The last species aestivated during the later part of summer and remained inactive until the next spring. However, sporadic activity was observed during rainy days in late summer and early fall.

If the difference in distance between points of capture over long and short periods of time is small or lacking, then limited movement is suggested. To test this, the relationship between the elapsed activity period and the distance between successive captures was compared. The recaptures were separated into two groups, those which had been recaptured in less than 100 days and those in more than 100 days (table 4). Although the average distance between recaptures was frequently farther with the longer period than with the shorter period, this difference was small, suggesting a limited movement for all four species.

When a turtle was captured three or more times, its first-last-capture distance (FLCD), ("the distance between the original point of capture and the last point of recapture," Carpenter, 1952) was compared to the maximum distance between successive captures. The first-last-capture distances were shorter than the maximum distances in 72 percent of 44 records of *K. s. hippocrepis*, in 85 percent of 7 records of *K. f. flavescens*, in 77 per cent of 13 records of *S. odoratus* and for the one record of *S. c. carinatus* (table 5). These data suggest that the turtles tend to return toward the point of original capture, thus indicating limited movement and the possible existence of a definite activity range.

In the studied areas, several individuals of the four species were recaptured in the same location during a period ranging from one day to 392 days (table 6). At Cowan Creek, 13 individuals of *K. s. hippocrepis* were recaptured at the point of original capture. From Honey Creek and the Mountain Fork River there were three and one recaptures respectively of S. c. carinatus. This was further evidence indicating limited movement of these turtles.

The high level of Lake Texoma flooded the lower one half of the gully of Cowan Creek from May through July of 1957. The water here reached depths of 20 to 30 feet. Almost all the turtles marked prior to the flood were recaptured near the points of their original capture after the flood waters receded.

In July of 1957, 15 K. s. hippocrepis were released at one point into Lake Texoma. During August of 1959, 7 of the 15 turtles were recovered within an estimated radius of 150 feet from the point of release.

The limited movement demonstrated by each of the four species suggests that they have homing ability which enables them to maintain their limited activity range.

The shape and size of the activity range varied from one individual to another and from species to species (figs. 26-31). Habitat types and habitat conditions are perhaps the main factors influencing the size and shape of the activity range. In Cowan Creek, Honey Creek, and the Mountain Fork River, the length of the activity range was based on the average distance between successive captures (table 4), while the width of the activity range was based on the average width of the river or creek, since these species confined their movements to water. No definite width was estimated for K. f. flavescens because of its frequent migrations over land from one body of water to another. The average length of the activity range for K. s. hippocrepis was 171.33 feet for 79 males, 203.62 feet for 115 females and 53.75 feet for 6 juveniles. The average width of Cowan Creek was 6 feet. The preceding data indicate that females have larger activity ranges than the males and juveniles. In S. odoratus, the males appear to have a larger activity range than the females. The average length for 39 males was 221.70 feet, while for 37 females, the average length was 145.90 feet. The average width of Honey Creek was 30 feet. Inadequate movement data for S. c. carinatus do not permit precise information about its activity range. However, for four males, one female, and seven juveniles, the average length of the activity range was 126.66 feet, 57 feet, and 114.40 feet respectively. The average width of the area studied in Mountain Fork River was 120 feet.

The movement data obtained from Berry's Pond showed the average distance between successive captures to be farther than that of the other three species. The average length of the activity range was 651.57 feet in 4 male records, 700.64 feet in 11 female records, and 588.84 feet in 17 juvenile records.

Since frequent migration over land is a characteristic of K. f. flavescens it was assumed that this contributed to their larger activity ranges. The wandering movement was probably due to forced migration away from unsuitable habitat conditions such as drought and food shortage. Carpenter (unpublished data) marked 130 individuals of K. f. flavescens in a seven acre area of Oliver Wildlife Preserve from 1954 to 1956. Several of the marked individuals were found dead in the Preserve as a result of the 1954 to 1956 drought. However, some of them probably moved out of the area during the drought. A total of 34 individuals of K. f. flavescens was collected from the same area during the spring of 1959 of which all were unmarked individuals.

A small body of water with suitable habitat conditions could limit the movement of K. f. flavescens. In the spring of 1959, 34 individuals were marked in Donita's Pond. Two months later all of them were recaptured from the same one acre pond.

Trapping from the peripheral regions of the studied areas (Cowan Creek, Honey Creek, and Mountain Fork River) yielded few marked individuals. One marked turtle from

Berry's Pond was recaptured from an adjacent pond 377 days later. The turtle must have traveled a minimum of 2,000 feet.

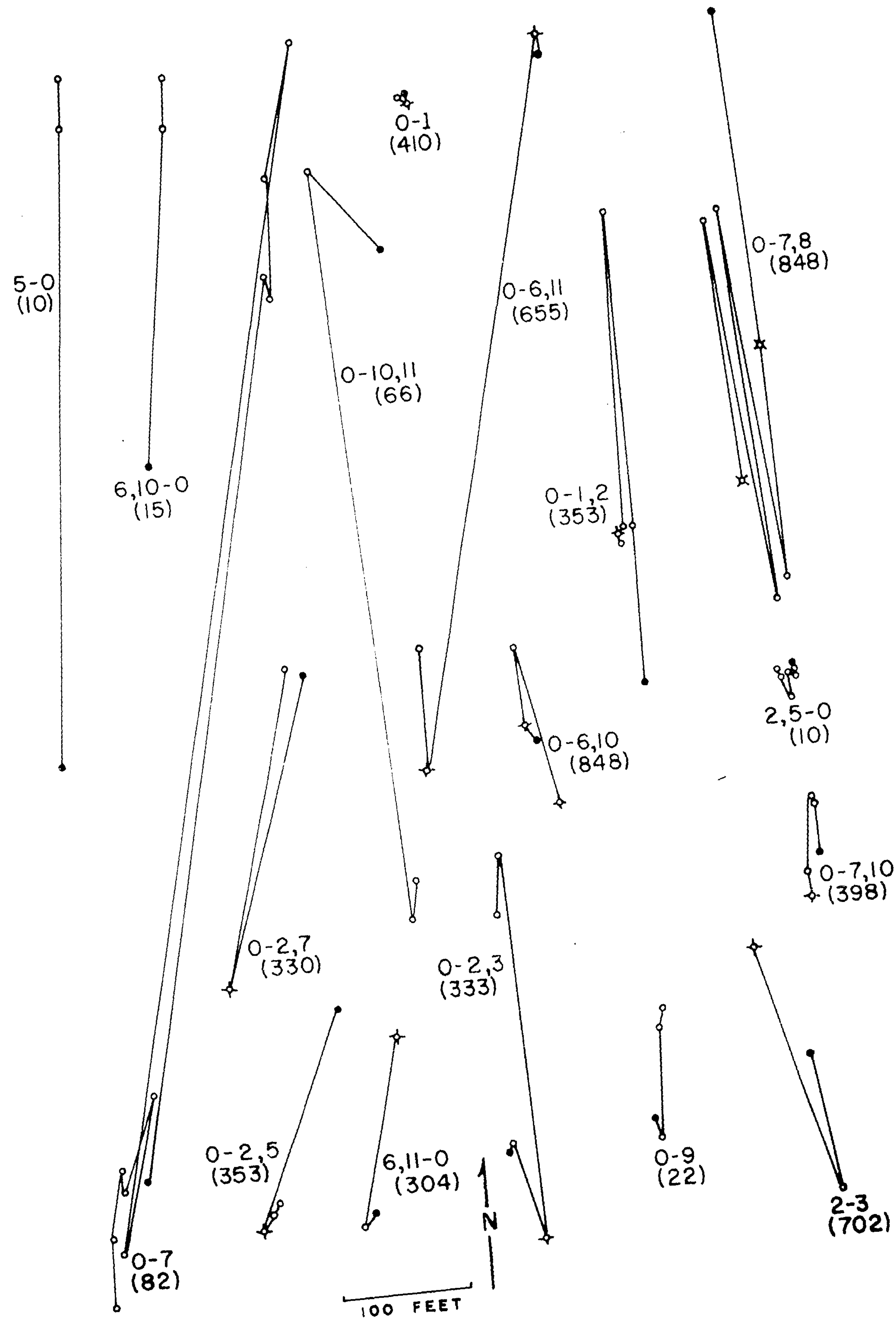
The Dalk method (1938) for estimating the shape and size of activity range was also considered in this study. Using this method, the lines between the points of capture represent the approximate boundary for the activity range. From records so plotted in figures 26-31 it appears that the size and shape of the activity range varies from one individual to another.

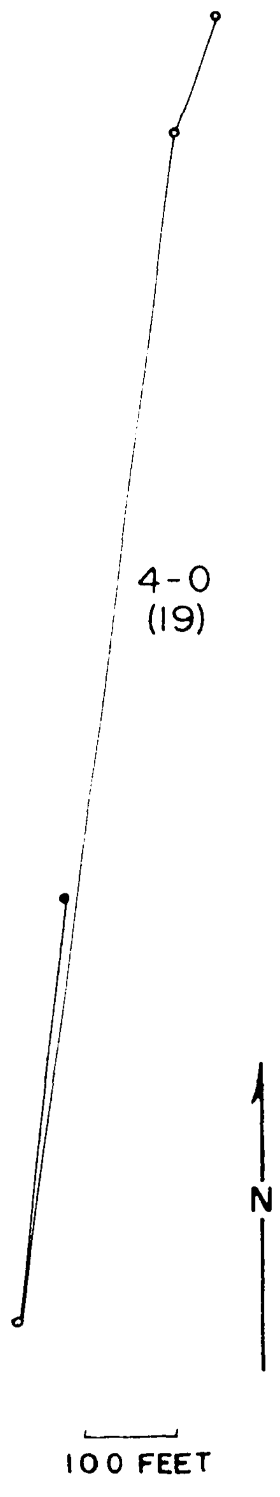
Figure 18

Individual patterns of movement by the male turtles of *Kinosternon subrubrum hippocrepis* captured three or more times at Cowan Creek.

- ● -Point of original capture.
- o -Point of recapture over less than one annual activity period.
- -○-Point of recapture over less than one annual activity period.
- □ -Point of recapture the same as the point of the original capture over less than one annual activity period.
- ■ -Point of recapture the same as the point of the original capture over more than one annual activity period.

Figures in parenthesis represent the periods in days between the first and last capture. Figures without parenthesis represent the code number of the turtles.

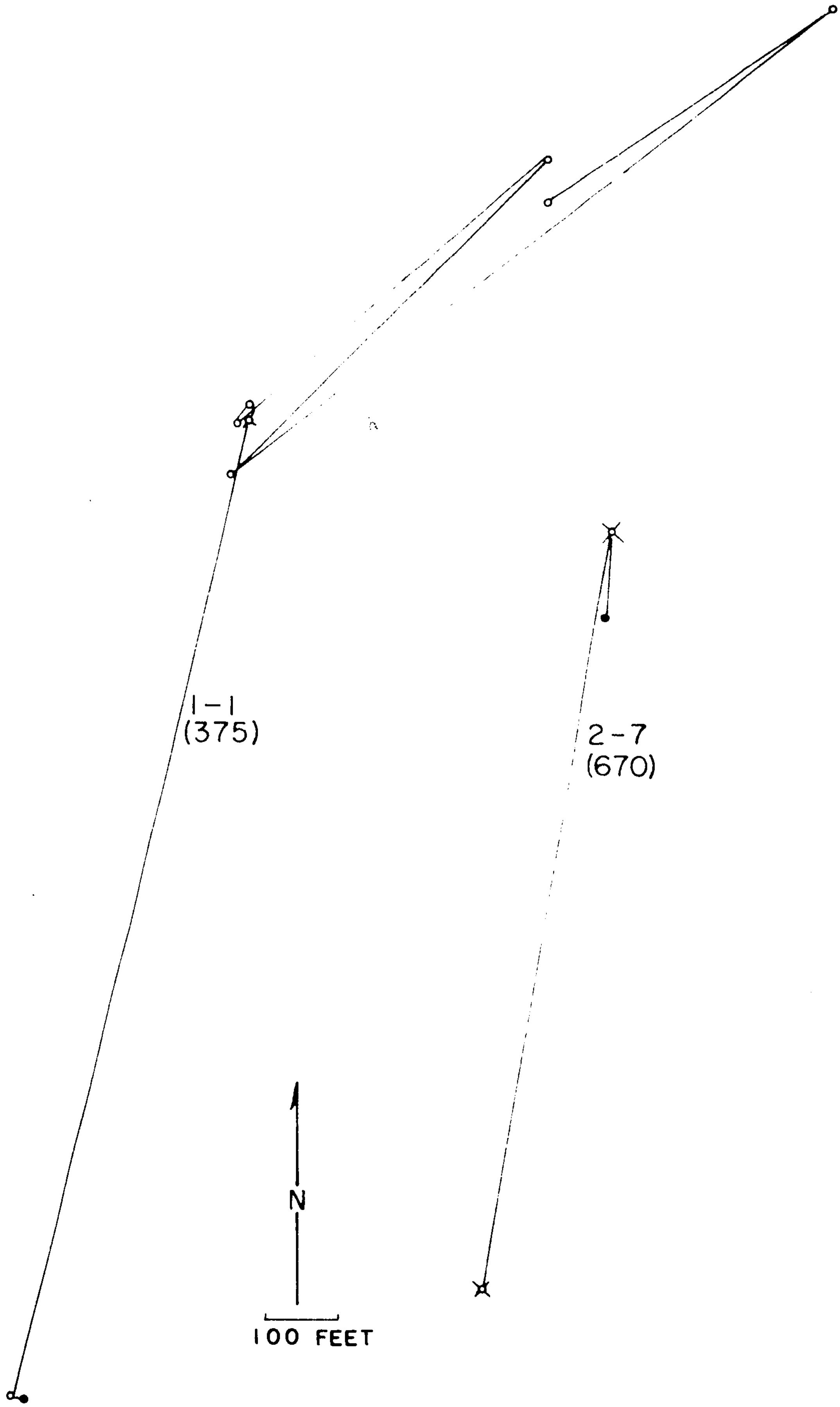

5-0
(10)
6,10-0
(15)
0-1
(410)
0-10,11
(66)
0-6,11
(655)
0-7,8
(848)
0-1,2
(353)
0-6,10
(848)
2,5-0
(10)
0-7,10
(398)
0-2,7
(330)
0-2,3
(333)
0-2,5
(353)
6,11-0
(304)
0-9
(22)
2-3
(702)
0-7
(82)
N
100 FEET

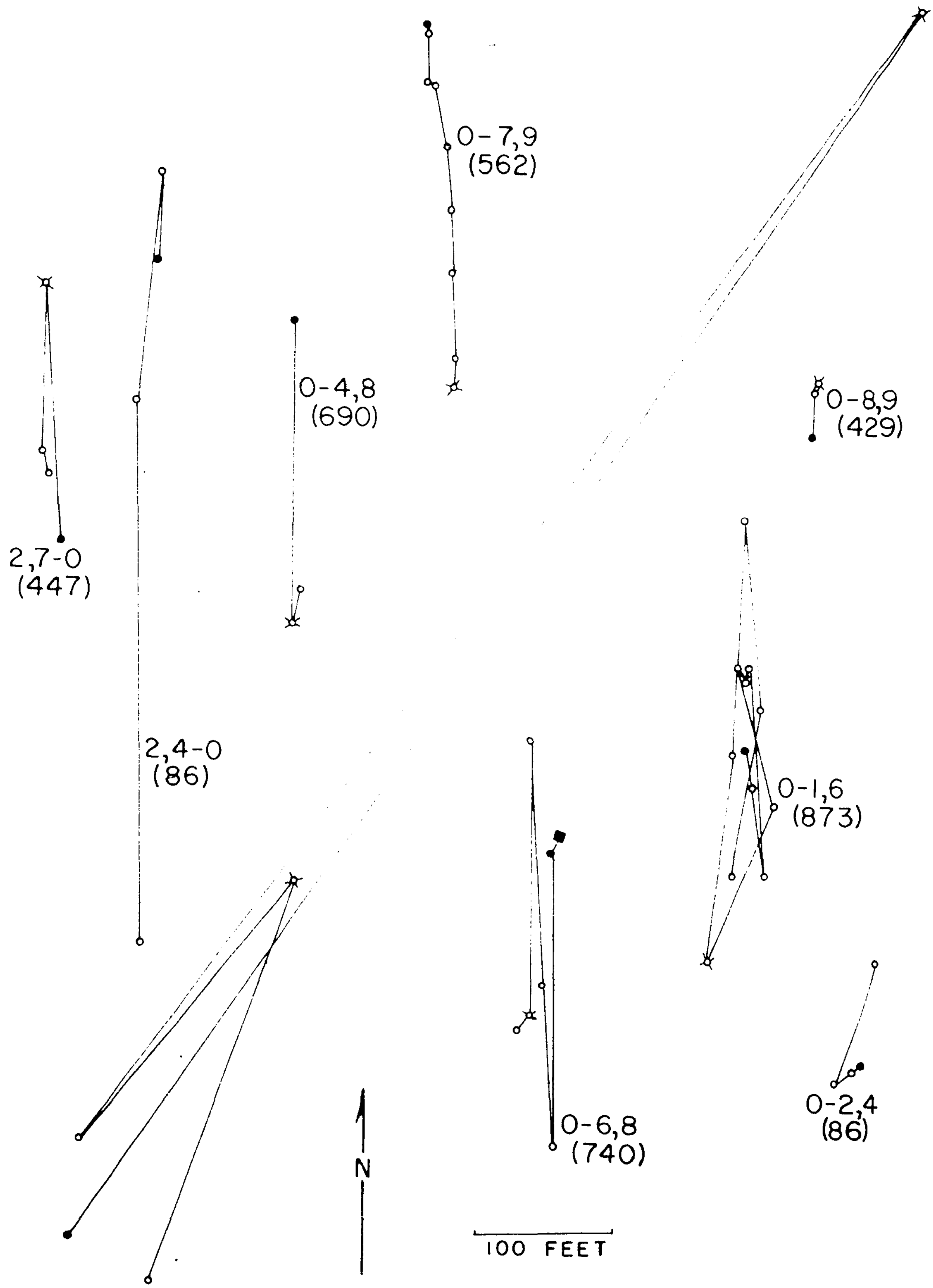


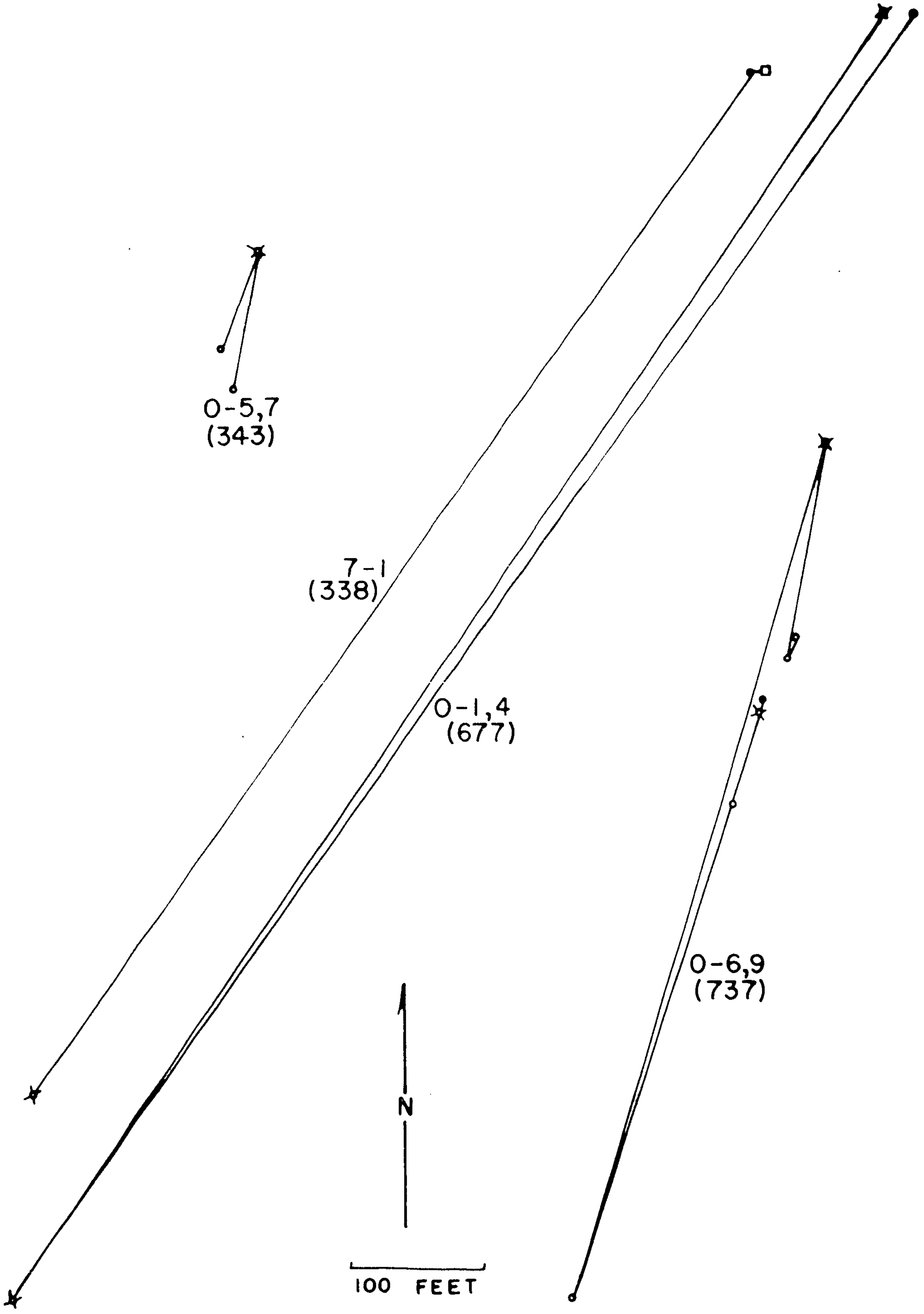
4-0
(19)
N
100 FEET

Figure 19

Individual patterns of movement by the female turtles of *Kinosternon subrubrum hippocrepis* captured three or more times at Cowan Creek. Symbols as in Figure 18.


1-1
(375)
2-7
(670)
N
100 FEET


0-7,9
(562)
0-4,8
(690)
2,7-0
(447)
0-8,9
(429)
2,4-0
(86)
0-1,6
(873)
0-6,8
(740)
0-2,4
(86)
N
100 FEET


0-5,7
(343)
7-1
(338)
0-1,4
(677)
0-6,9
(737)
N
100 FEET

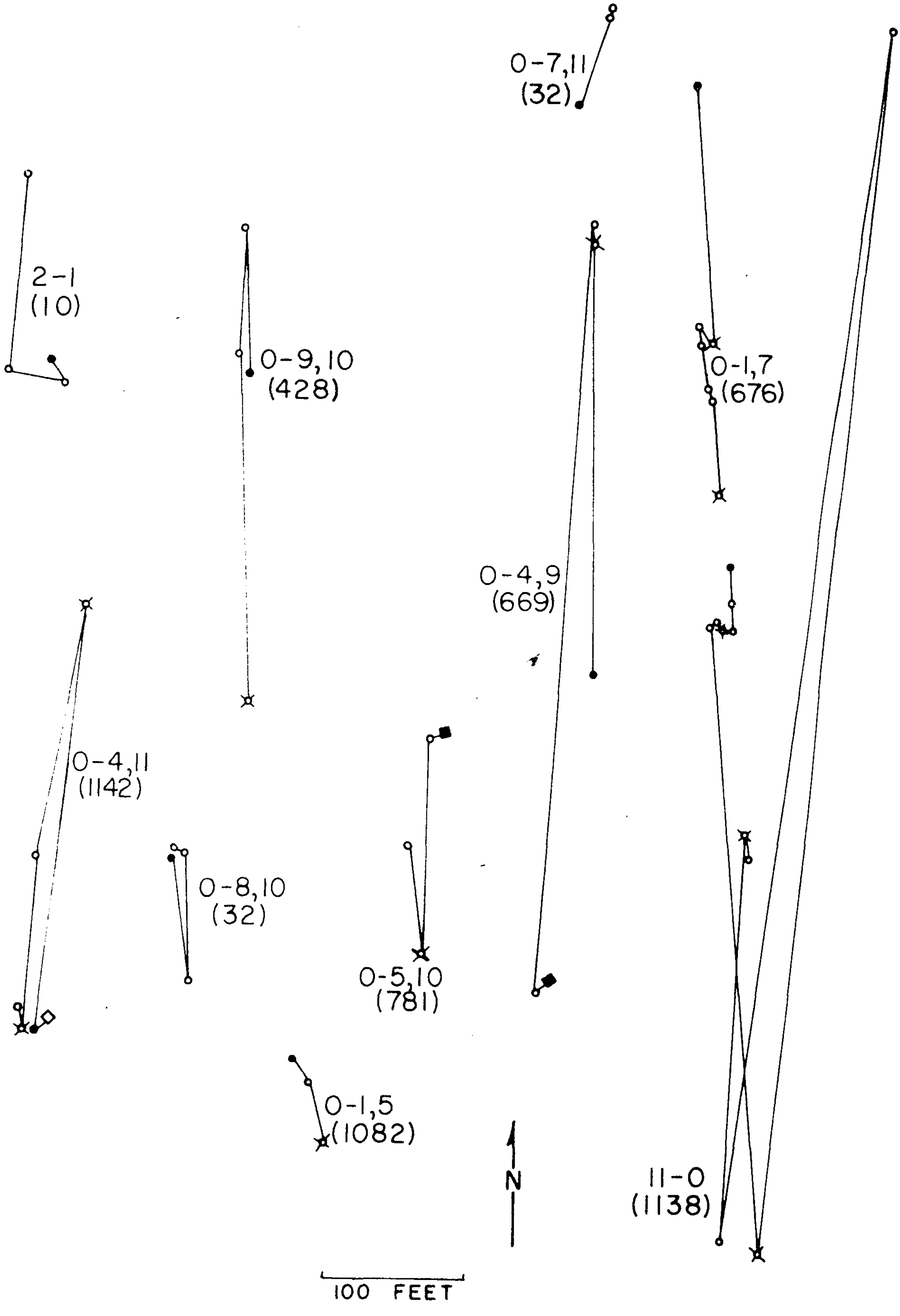

0-7,11
(32)
2-1
(10)
0-9,10
(428)
0-1,7
(676)
0-4,9
(669)
0-4,11
(1142)
0-8,10
(32)
0-5,10
(781)
0-1,5
(1082)
N
11-0
(1138)
100 FEET

Figure 20

Individual patterns of movement by the juvenile turtles of *Kinosternon subrubrum hippocrepis* captured three or more times at Cowan Creek. Symbols as in Figure 18.

0-1,8
(1071)
0-3,10
(685)
N
100 FEET

Figure 21

Individual patterns of movement by the juveniles of *Kinosternon flavescens flavescens* captured three or more times at Berry's Pond. Symbols as in Figure 18.

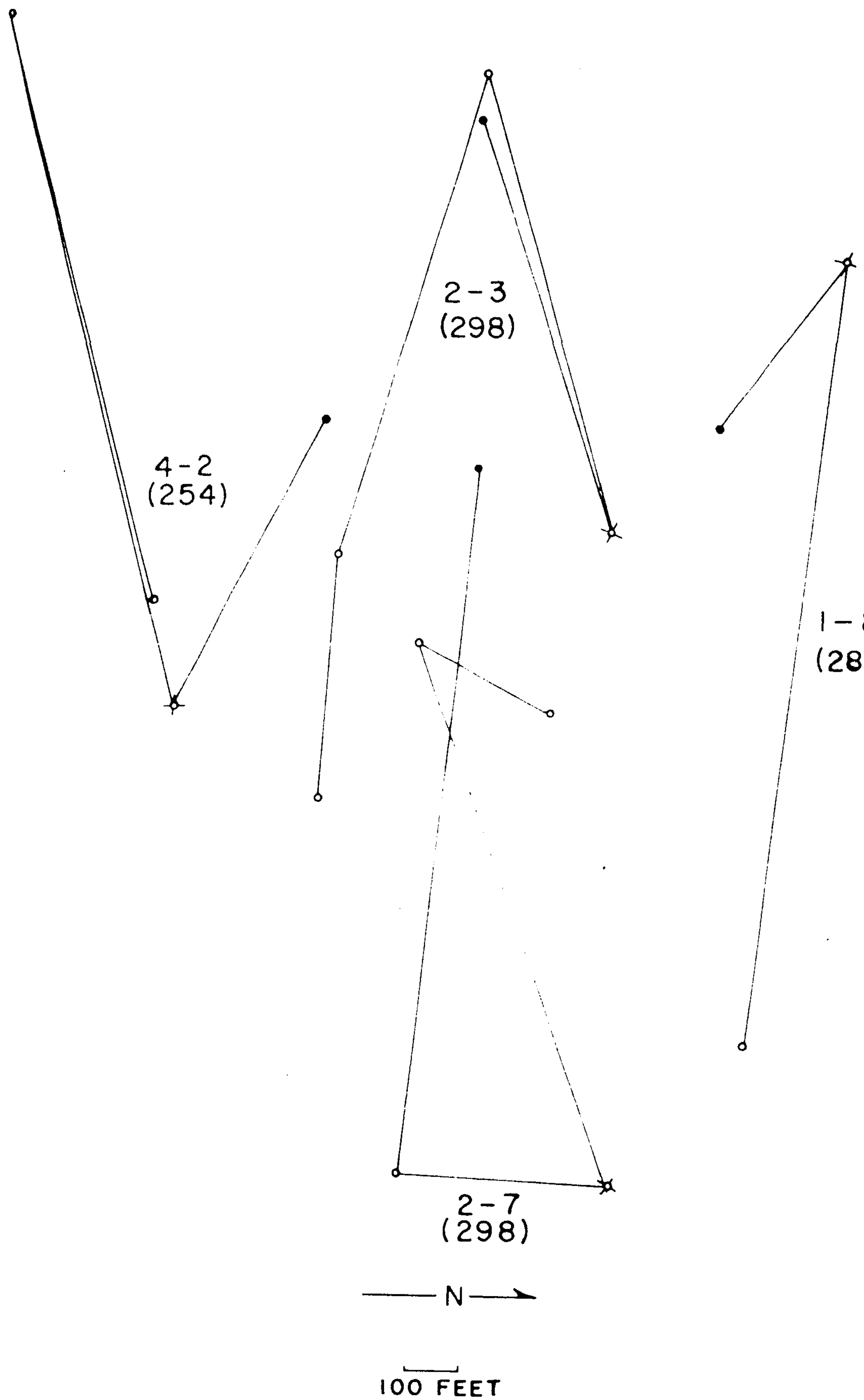
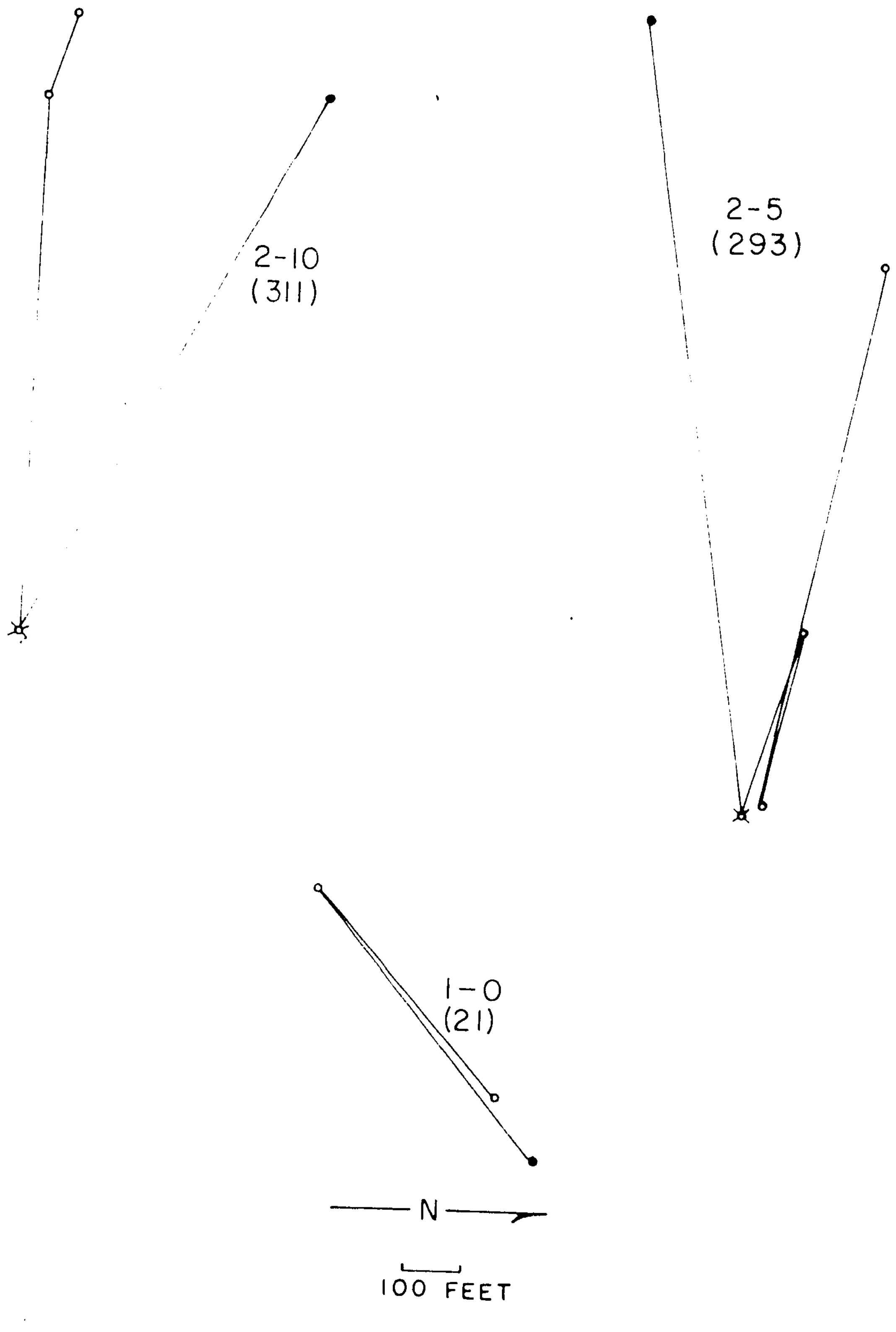

4-2
(254)
2-3
(298)
1-8
(287)
2-7
(298)
N
100 FEET

Figure 22

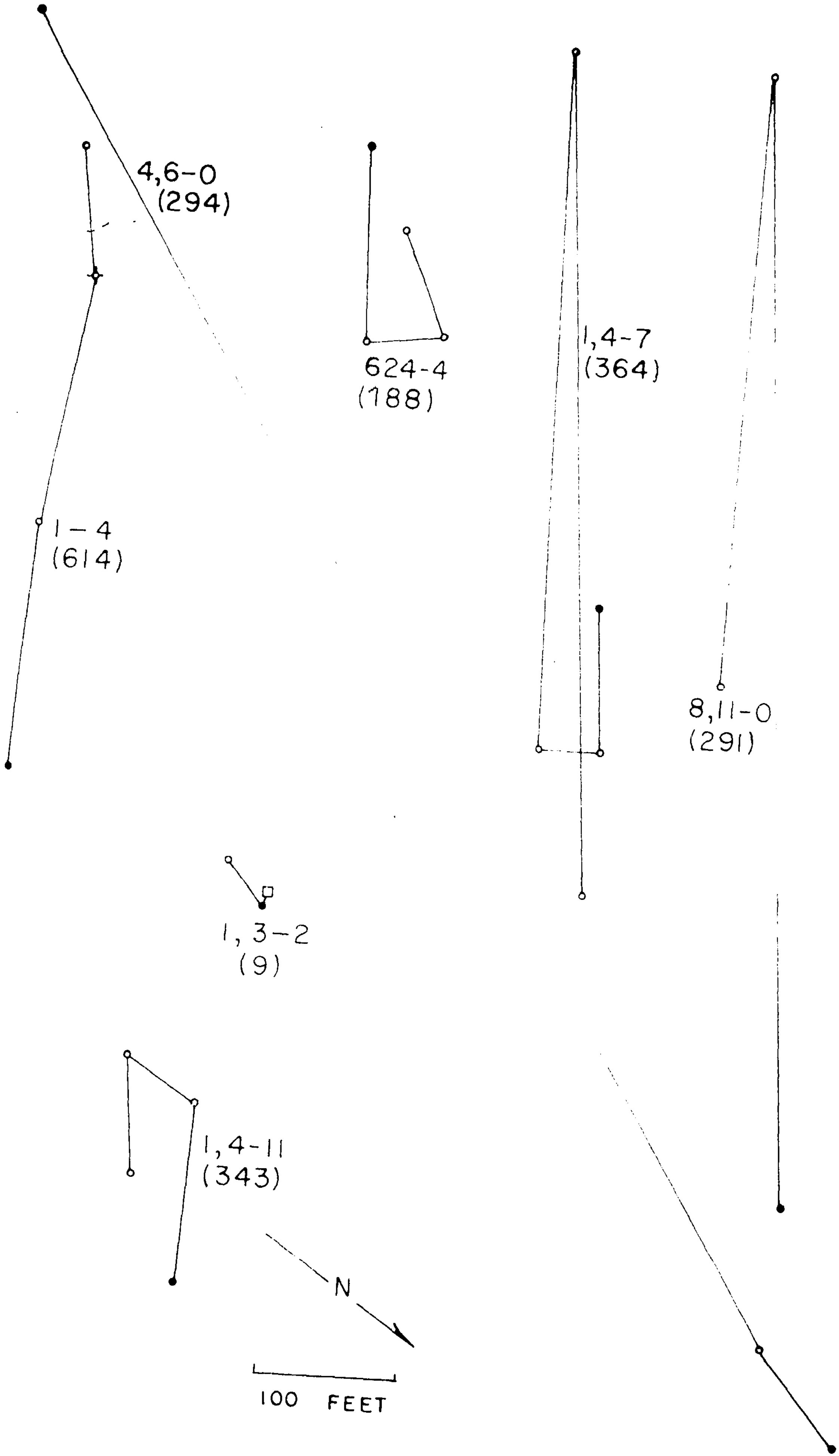
Individual patterns of movement by the females of *Kinosternon flavescens flavescens* captured three or more times at Cowan Creek. Symbols as in Figure 18.



2-10
(311)
2-5
(293)
1-0
(21)
N
100 FEET

Figure 23

Individual patterns of movements by the males of *Sternothaerus odoratus* captured three or more times at Honey Creek. Symbols as in Figure 18.



4,6-0
(294)
624-4
(188)
1,4-7
(364)
1-4
(614)
8,11-0
(291)
1,3-2
(9)
1,4-11
(343)
N
100 FEET

Figure 24

Individual patterns of movement by the females of *Sternothaerus odoratus* captured three or more times at Honey Creek. Symbols as in Figure 18.

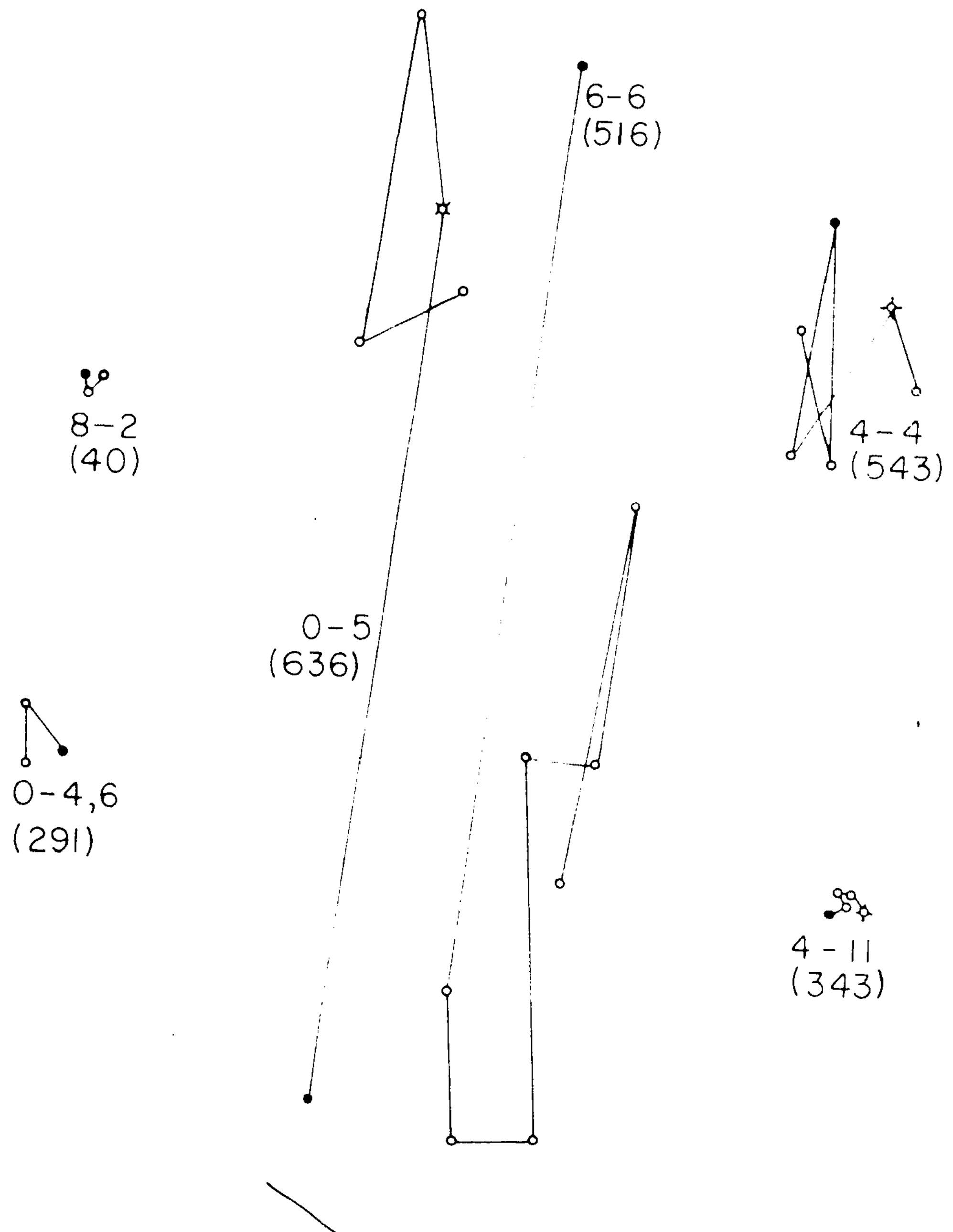

6-6
(516)
8-2
(40)
4-4
(543)
0-5
(636)
0-4,6
(291)
4-11
(343)
N
100 FEET

Figure 25

Individual patterns of movement by the males of Sternothaerus carinatus carinatus captured three or more times at the Mountain Fork River. Symbols as in Figure 18.

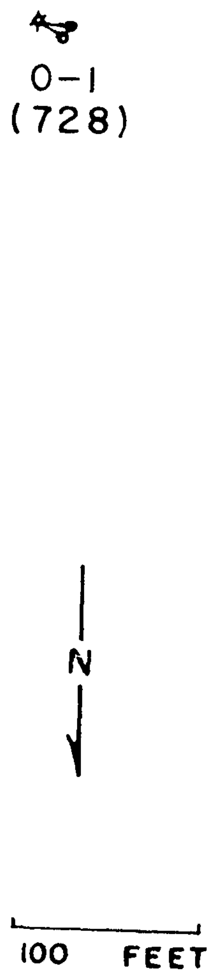

O-1
(728)
N
100 FEET

Figure 26

Different shapes and sizes of the activity range in the males of *Kinosternon subrubrum hippocrepis*. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.

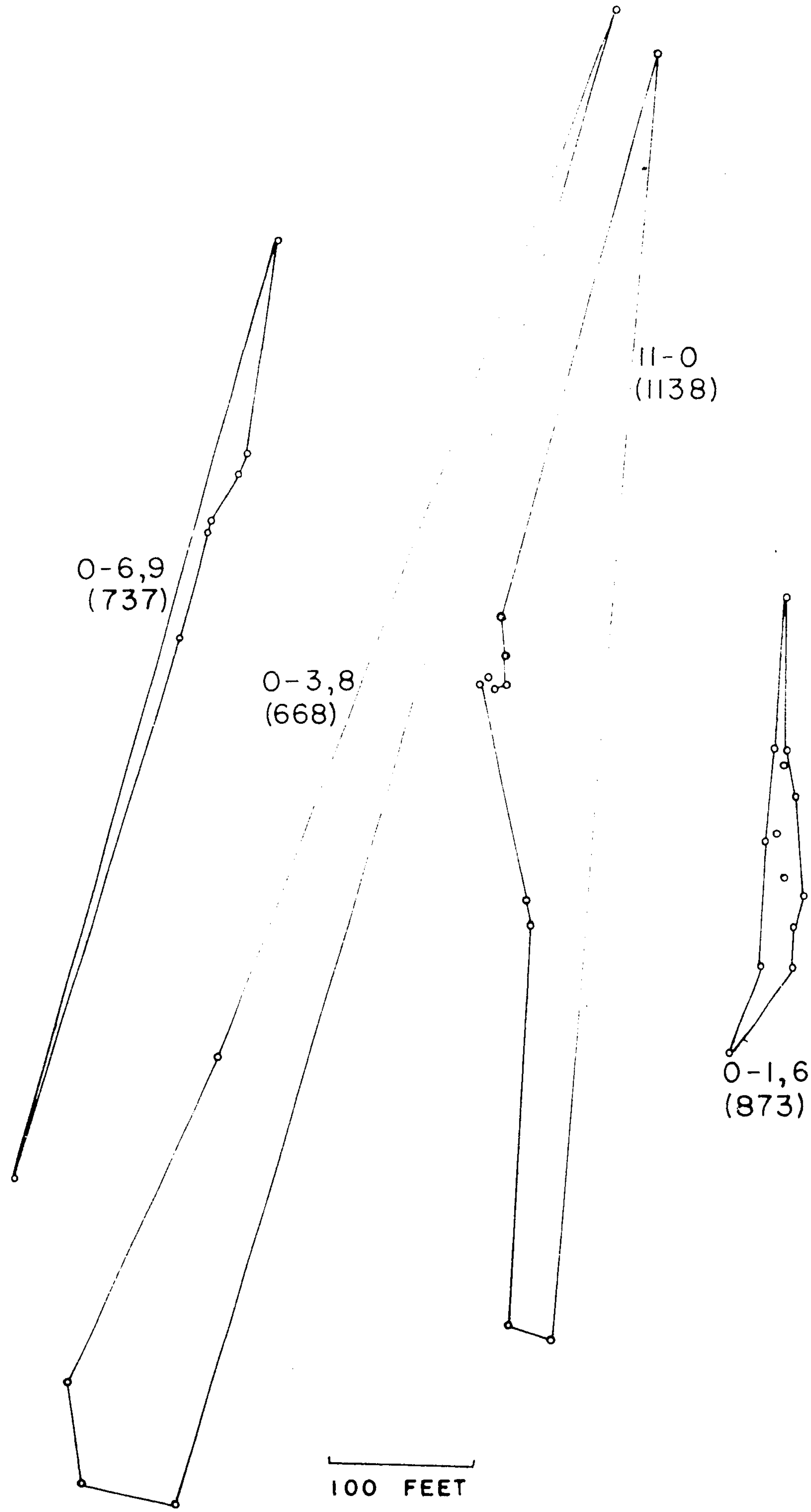
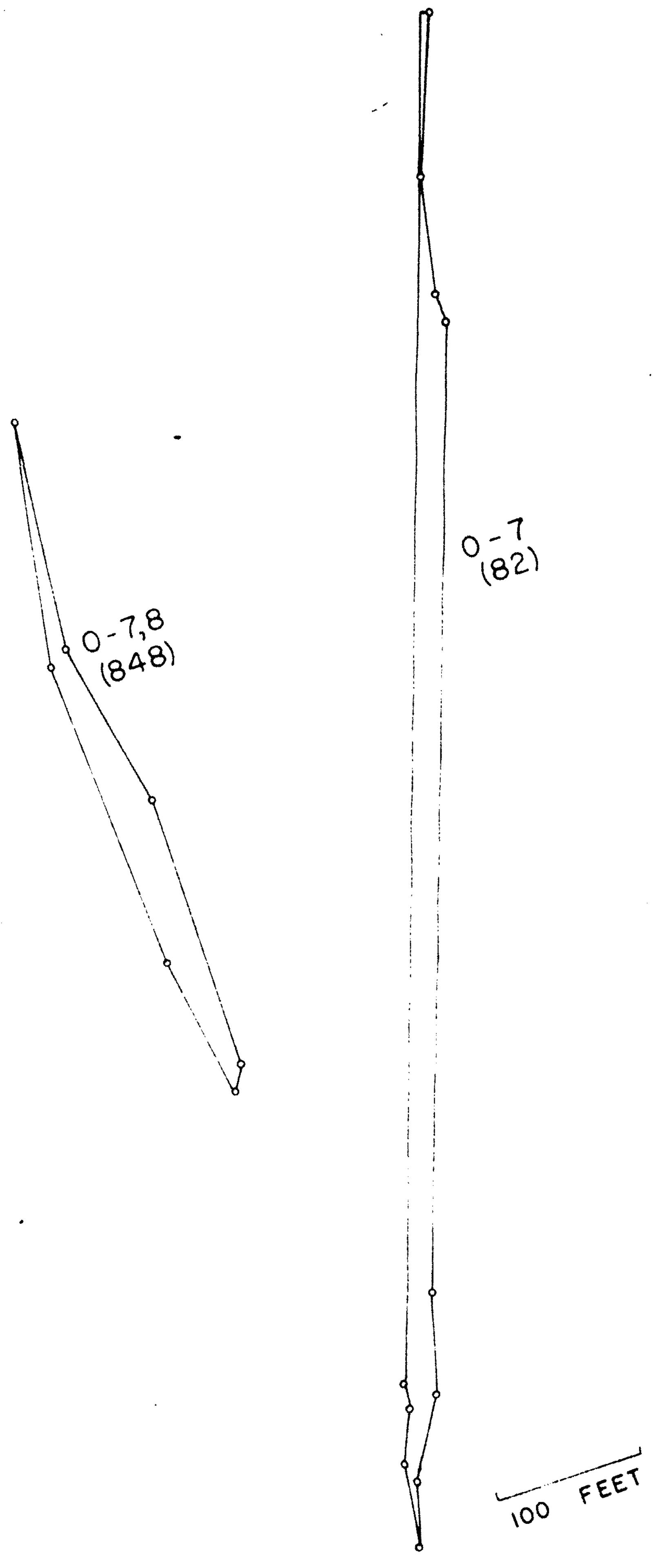

0-6,9
(737)
0-3,8
(668)
II-0
(1138)
0-1,6
(873)
100 FEET

Figure 27

Different shapes and sizes of the activity range in the females of *Kinosternon subrubrum hippocrepis*. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.



0-7,8
(848)
0-7
(82)
100 FEET

Figure 28

Different shapes and sizes of the activity range in the juveniles of *Kinosternon flavescens flavescens*. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.

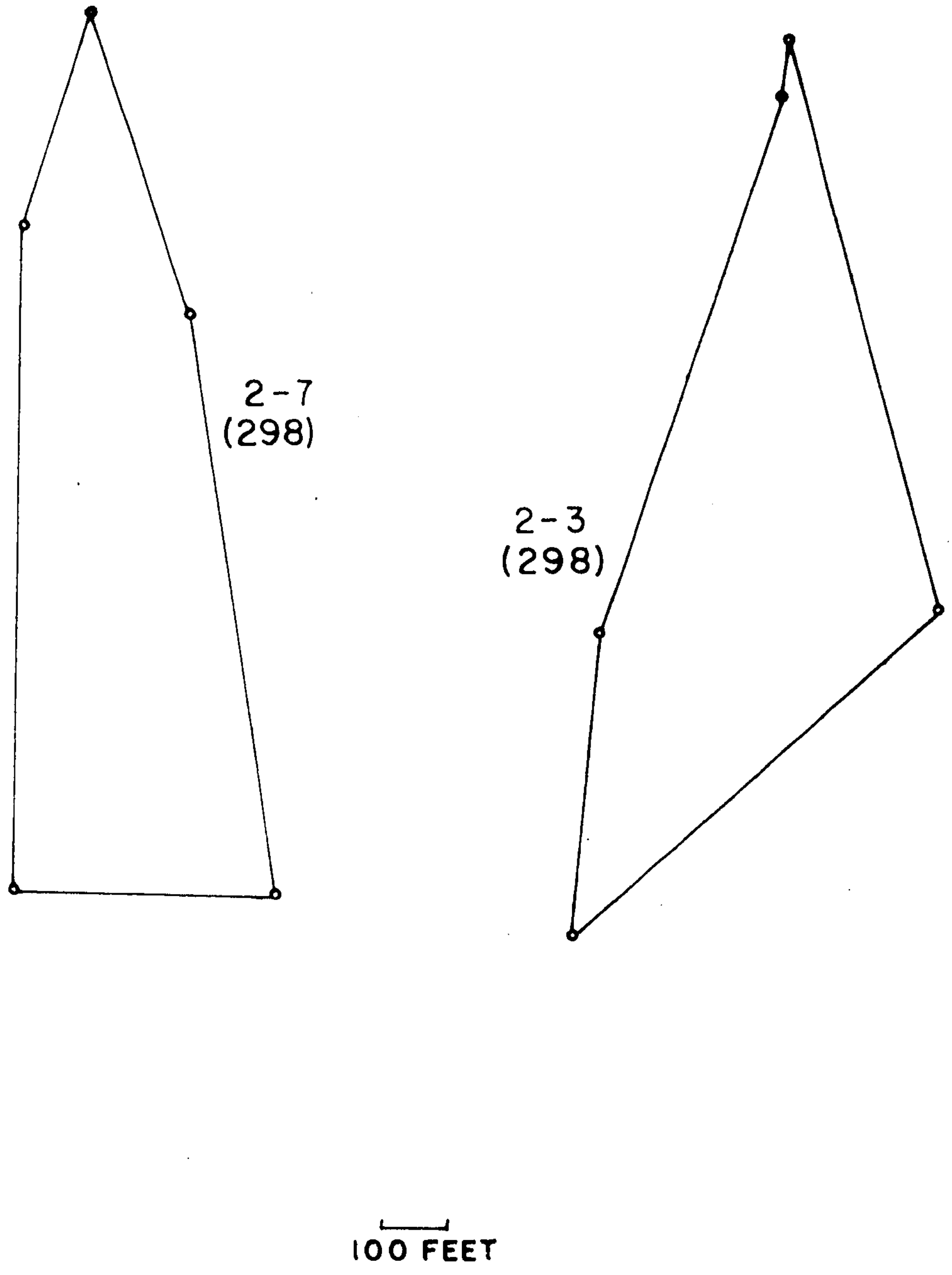

2-7
(298)
2-3
(298)
100 FEET

Figure 29

Different shapes and sizes of the activity range in the females of Kinosternon flavescens flavescens. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.

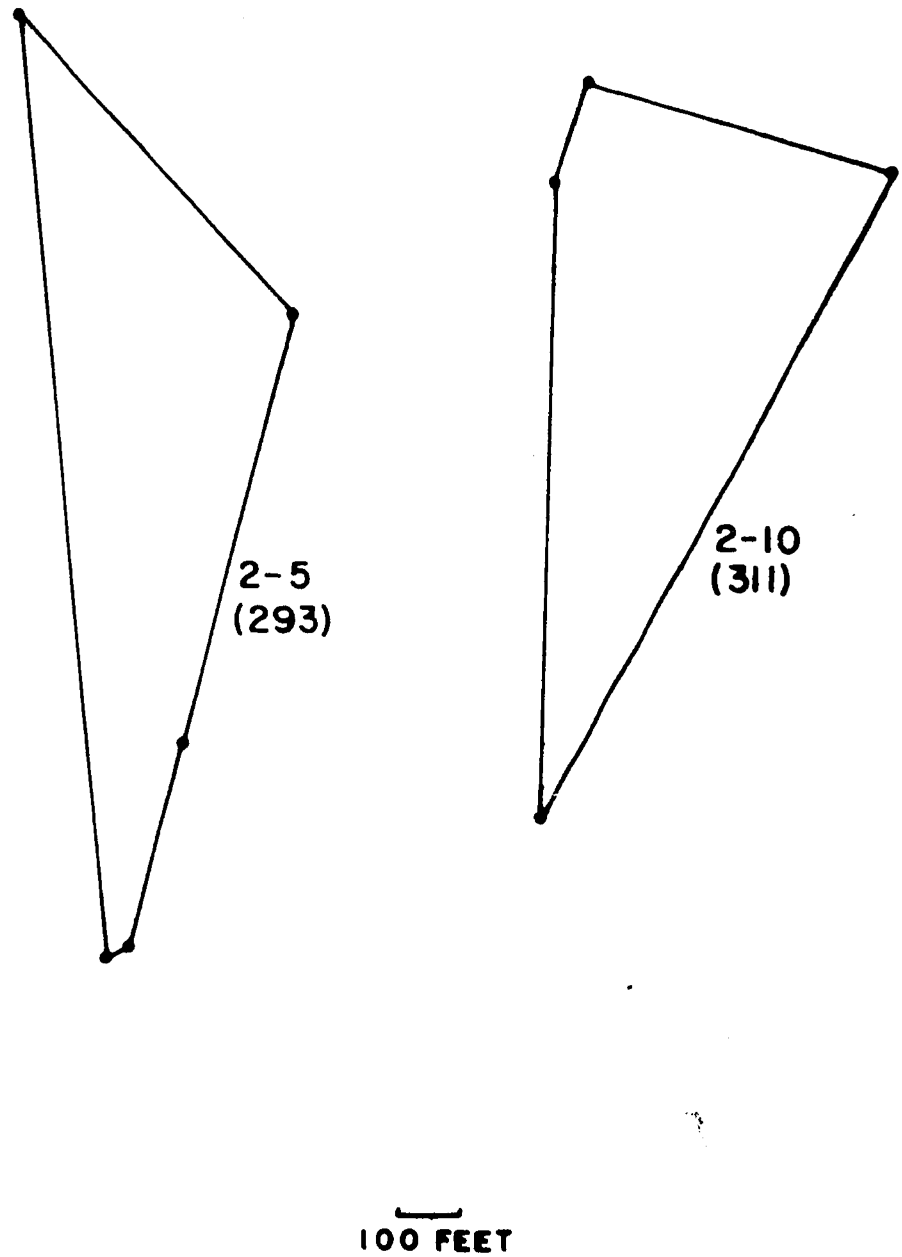

2-5
(293)
2-10
(311)
100 FEET

Figure 30

Different shapes and sizes of the activity range in the males of <u>Sternothaerus</u> <u>odoratus</u>. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.

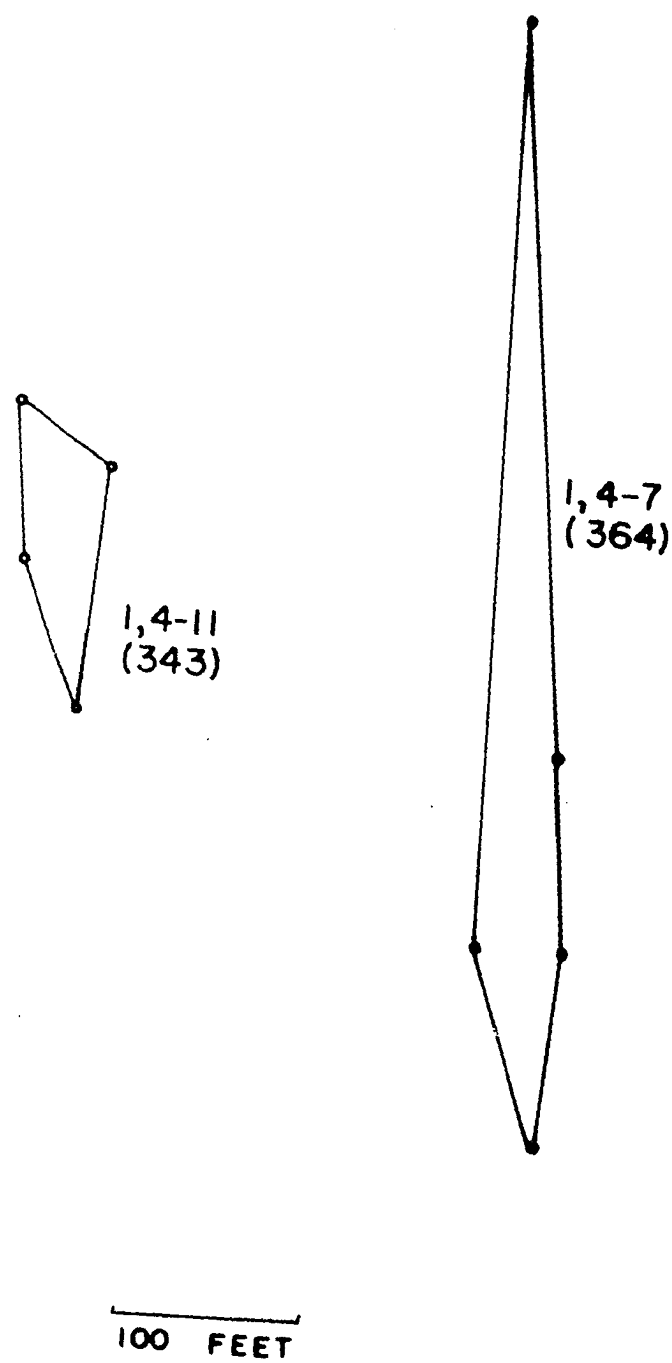

1,4-11
(343)
1,4-7
(364)
100 FEET

Figure 31

Different shapes and sizes of the activity range in the females of Sternothaerus odoratus. Each point represents the spot of capture. The lines between the points are assumed to represent the boundaries of the activity range.

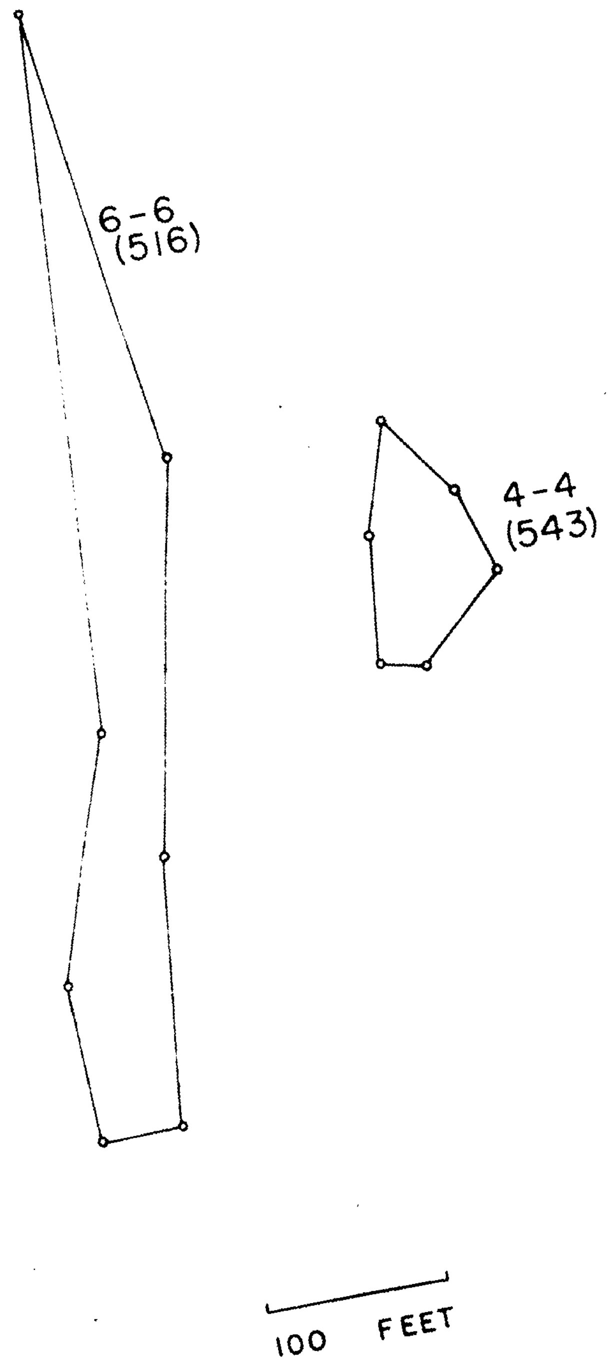

6-6
(516)
4-4
(543)
100 FEET

TABLE 4.--Average distance between consecutive points of capture for periods of 100 days or more and for less than 100 days

<u>Sternothaerus odoratus</u>

Activity period	Number of records	Av. dist. (in feet) between consecutive points of capture	Min. and max. dist. (in feet) between consecutive points of capture
Less than 100 days			
Males	15	216.66	(0) (600)
Females	23	126 ft.	(6) (1124)
Total	38	161.78	(6) (1724)
More than 100 days			
Males	24	226.75	(0) (1062)
Females	14	165.80	(12) (510)
Total	38	204.31	(12) (1572)

TABLE 4.--Continued

Activity period	Number of records	Av. dist. (in feet) between consecutive points of capture	Min. and max. dist. (in feet) between consecutive points of capture
	Kinosternon flavescens flavescens		
Less than 100 days			
Males	1	799.53	
Females	7	556.272	(148.87)(942.89)
Juveniles	10	802.83	(181.98)(1428.12)
Total	18	706.76	(148.87)(1428.12)
More than 100 days			
Males	3	503.61	(799.53)(490.74)
Females	4	845.017	(275.70)(1361.95)
Juveniles	7	374.84	(11.02)(777.47)
Total	14	536.77	(11.02)(1428.12)

TABLE 4.--Continued

Activity period	Number of records	Av. dist. (in feet) between consecutive points of capture	Min. and max. dist. (in feet) between consecutive points of capture
	Kinosternon subrubrum hippocrepis		
Less than 100 days			
Males only	57	154.29	(2) (1248)
Females only	81	140.27	(0) (1020)
Juveniles	2	0	
Total	140	143.97	(0) (1248)
More than 100 days			
Males only	22	188.36	(3) (1200)
Females only	34	266.97	(0) (1340)
Juveniles	4	53.75	(0) (124)
Total	60	223.93	(0) (1340)

TABLE 4.--Continued

Sternothaerus carinatus carinatus

Activity period	Number of records	Av. dist. (in feet) between consecutive points of capture	Min. and max. dist. (in feet) between consecutive points of capture
Less than 100 days			
Males	1	0	
Females	0		
Juveniles	1	51	
Total	2	25.50	
More than 100 days			
Males	3	126.66	(15) (299)
Females	1	57	
Juveniles	5	177.80	(45) (308)
Total	9	147.33	(15) (308)

TABLE 5.--A comparison of the maximum distance between points of capture and the first-last-capture-distance for individuals captured more than twice

Kinosternon subrubrum hippocrepis

Code number	Number of captures for each turtle	Sex	Max. dist. between consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
13	3	female	1152	20	677
14	3	female	44	62	1082
72	3	female	210	186	690
78	3	female	110	32	343
92	3	female	63	70	32
93	3	female	30	38	429
105	3	female	920	916	338
115	3	female	1020	912	670
1	3	male	4	4	410
26	3	male	270	16	330

TABLE 5.--Continued

Code number	Number of captures for each turtle	Sex	Max. dist. between consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
46	3	male	510	528	10
88	3	male	147	136	305
100	3	male	261	300	15
22	4	female	378	476	86
23	4	female	90	68	17
27	4	female	180	48	447
81	4	female	150	76	781
90	4	female	30	126	4
96	4	female	243	230	428
102	4	female	135	128	10
94	4	female	90	4	10
96	4	female	243	428	32

TABLE 5.--Continued

Code number	Number of captures for each turtle	Sex	Max. dist. between consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
24	4	male	90	160	428
40	4	male	99	84	353
45	4	male	1248	928	22
86	4	male	125	30	19
87	4	male	570	464	848
98	4	male	501	484	655
21	5	male	294	164	66
91	5	male	60	34	333
36	5	female	1050	68	398
73	5	female	540	226	668
12	6	male	240	108	669
75	6	female	300	20	353

TABLE 5.--Continued

Code number	Number of captures for each turtle	Sex	Max. dist. between consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
16	7	female	180	286	1142
84	7	female	204	108	676
85	7	female	654	124	740
90	9	female	60	126	737
101	9	female	1340		562
11	11	female	861	204	1837
15	12	female	165	88	876
38	11	male	930	100	82
89	7	male	393	356	848
99	7	male	20	12	10

TABLE 5.--Continued

Code number	Number of captures for each turtle	Sex	consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
		Kinosternon flavescens flavescens			
44	3	female	596	116	21
5	4	female	1053	469	311
21	5	female	1362	590	293
11	3	juvenile	1428	1119	287
32	4	juvenile	1274	452	254
2	5	juvenile	1285	463	298
19	5	juvenile	465	725	283
		Sternothaerus carinatus carinatus			
10	3	male	15	0	728

TABLE 5.--Continued

Code number	Number of captures for each turtle	Sex	Max. dist. between consecutive points (feet)	FLCD (feet)	Activity period elapsed (days) between first and last capture
		Sternothaerus odoratus			
40	3	female	14	10	81
165	3	female	32	20	291
7	5	female	490	448	636
126	5	female	12	20	343
99	6	female	130	66	543
132	8	female	506	22	561
110	3	male	40	0	9
144	3	male	1060	1180	294
160	3	male	784	378	291
14	4	male	174	434	614
207	4	male	126	74	343
214	4	male	138	60	188
204	5	male	584	204	364

TABLE 6.--Number of turtles recaptured at the same point of original capture in relation to the elapsed activity period

Number of records	Elapsed activity period in days
Kinosternon subrubrum hippocrepis	
1	1
1	2
1	4
1	7
1	8
1	10
1	23
1	57
1	290
1	390
1	392
Sternothaerus carinatus carinatus	
1	1
Sternothaerus odoratus	
1	8
1	51
1	366

CHAPTER VI

GROWTH

The carapace length, shell depth and the width between the bridges were recorded for each capture and recapture of a turtle. These data were used in two ways to determine growth: (1) the increase in carapace length per unit of time, and (2) the relationship between carapace length and the number of "annual rings" on the carapace scutes.

The growth periods of the four species were limited to the warm months; for S. odoratus - 190 days, S. c. carinatus - 180 days, K. s. hippocrepis - 170 days, and K. f. flavescens - 90 days. Hatchlings taken during early spring and late fall showed no growth until late spring.

The difference in carapace length between consecutive captures divided by the carapace length at the first capture gave the percentage increase in length for the elapsed period and was then divided by the number of, or fraction of, growing seasons elapsed to obtain the length increase per growing season.

Juveniles of the four species between 2.10 cm and 6.00 cm showed a pronounced increase in carapace length after which the growth rate markedly decreased (figs. 32-35 and table 6).

When the date of capture was plotted against the length of the carapace (figs. 36-39) no sex differences in length were apparent and only the hatchlings formed a distinguishable group. The hatchlings appeared in the population sometime between May and October.

There was some intra-specific variation in the growth rate which was possibly due in part to the considerable variation in the size of hatchlings. The size range of hatchlings was 2.10 cm to 2.70 cm in _K. s. hippocrepis_, 2.10 cm to 3.00 cm in _K. f. flavescens_, 2.00 cm to 2.60 cm in _S. odoratus_ and 2.30 cm to 3.10 cm in _S. c. carinatus_. Similarly, Risley (1933) stated that there was great variation in the size of _S. odoratus_ at hatching, the carapace length ranging from 1.9 cm to 2.5 cm. Possibly the amount of food available and the degree of suitability of habitat might also be responsible for some variation in the growth rates of the four species.

The estimation of growth indicated certain age-size relationships when using the "annual rings" of the carapace or plastron. Coker (1920) was able to determine the age of the diamondback terrapins by counting the rings on the carapace or plastron. He said that:

> As the terrapin grows each scute extends its area peripherally and, commonly, in all directions. Thus with each period of growth, a ring of tissue is added, separated from the central area (areola), or the preceding ring, by a line of depression.

Risley (1933) and Tinkle (1956) used this method to determine a size-age ratio in S. odoratus and S. c. carinatus. The growth curves for S. odoratus and S. c. carinatus in figure 40 are similar to those of Tinkle and Risley. In the four species the "ring count" method was useful up to the tenth year of age, after which the rings were so close together, presumably due to slowness of growth, that it was difficult to make any accurate age determinations (a difficulty also encountered by Tinkle and Risley). The curves in figure 40 were plotted using computed means for carapace lengths at each age and represent a total of 74 K. s. hippocrepis, 761 K. f. flavescens, 132 S. odoratus, and 25 S. c. carinatus. There is a comparable increase during the first six years, after which the growth rate steadily declined in S. odoratus and K. s. hippocrepis, while S. c. carinatus and K. f.

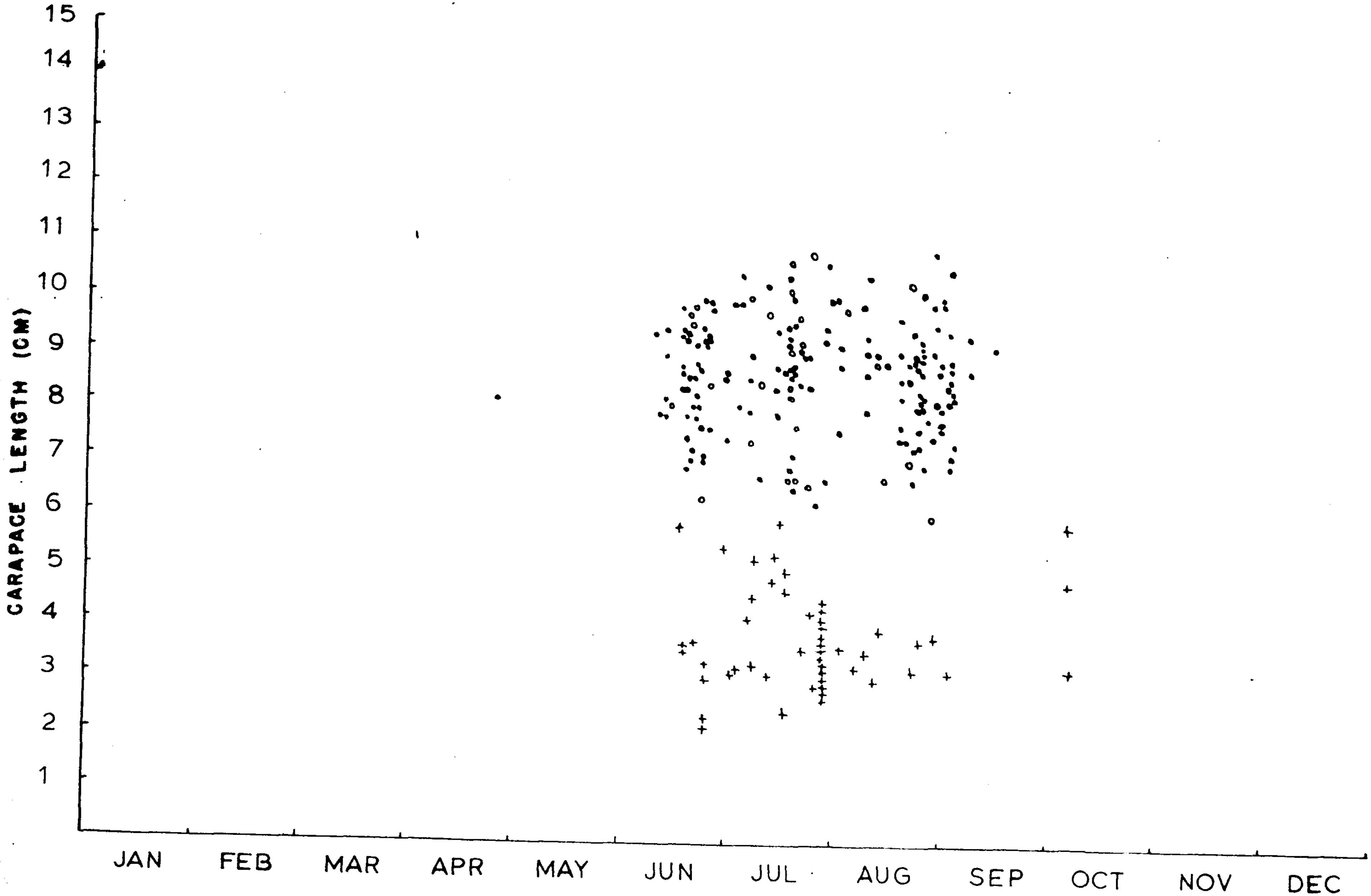
flavescens continued at approximately the same rate. Among the turtles used for the "ring count" method, there was a great variation in the sizes of the turtles of each species relative to a certain age, indicating possible individual differences in growth rate. Since this size-age variation exists, the investigator felt that growth in the four species may be limited by age rather than size. It is probable that these turtles have indeterminate growth, increasing in length throughout life, though at a slower rate with increasing age. Records for 35 *K. s. hippocrepis*, ranging in carapace length from 6.55 cm to 10.80 cm, 6 *K. f. flavescens*, ranging from 8.70 cm to 13.22 cm, 15 *S. odoratus*, ranging from 7.00 cm to 8.30 cm, and 3 *S. c. carinatus* ranging from 11.35 cm to 14.20 cm, showed no apparent growth over a period ranging from one to three years.

The data using both methods showed some similarity in the growth rate for the four species, especially for individuals between 2.10 cm and 6.00 cm in length.

A total of 16 *K. s. hippocrepis*, 10 *K. f. flavescens*, 3 *S. odoratus*, and 2 *S. c. carinatus* were kept two years in captivity without any apparent growth. These turtles were fed on an average of about once a week throughout the year. The annual rings on the carapace or plastron indicated that these captive turtles were past ten years of age.

Figure 32

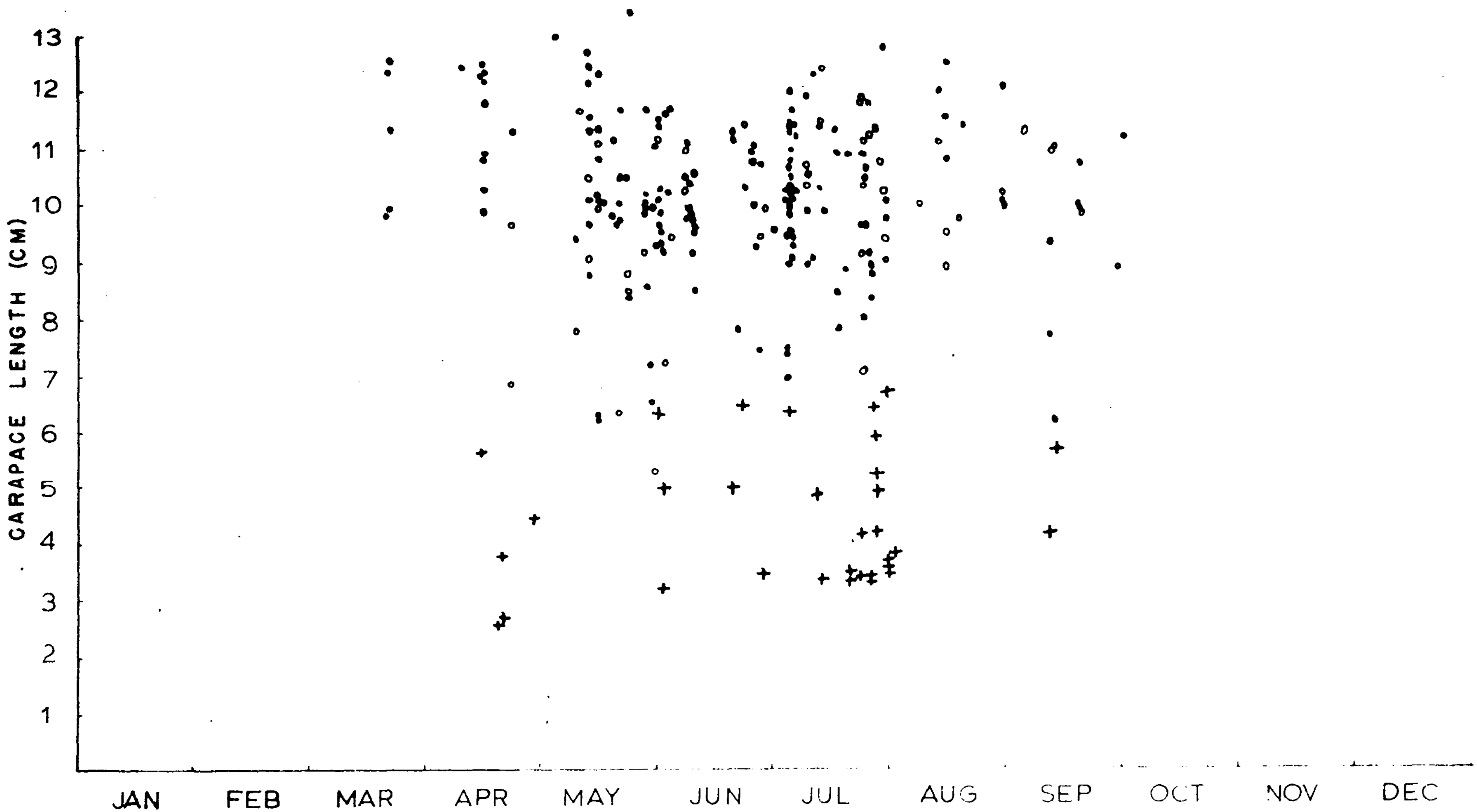
The relationship between body length and date of capture for *Kinosternon subrubrum hippocrepis* in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



CARAPACE LENGTH (CM)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 33

The relationship between body length and date of capture for *Kinosternon flavescens flavescens* in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



CARAPACE LENGTH (CM)
13
12
11
10
9
8
7
6
5
4
3
2
1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 34

The relationship between body length and date of capture for <u>Sternothaerus</u> <u>odoratus</u> in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.

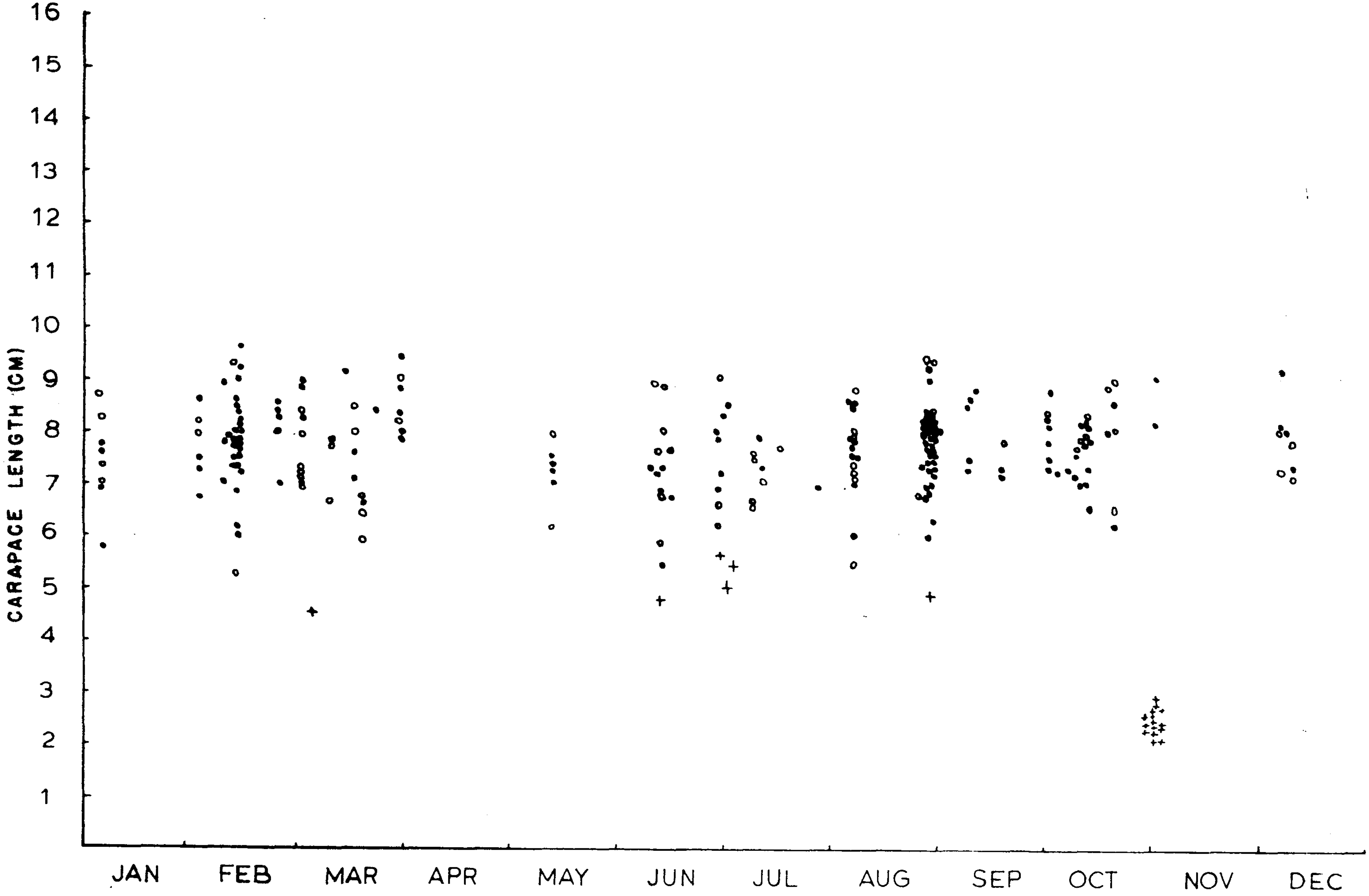
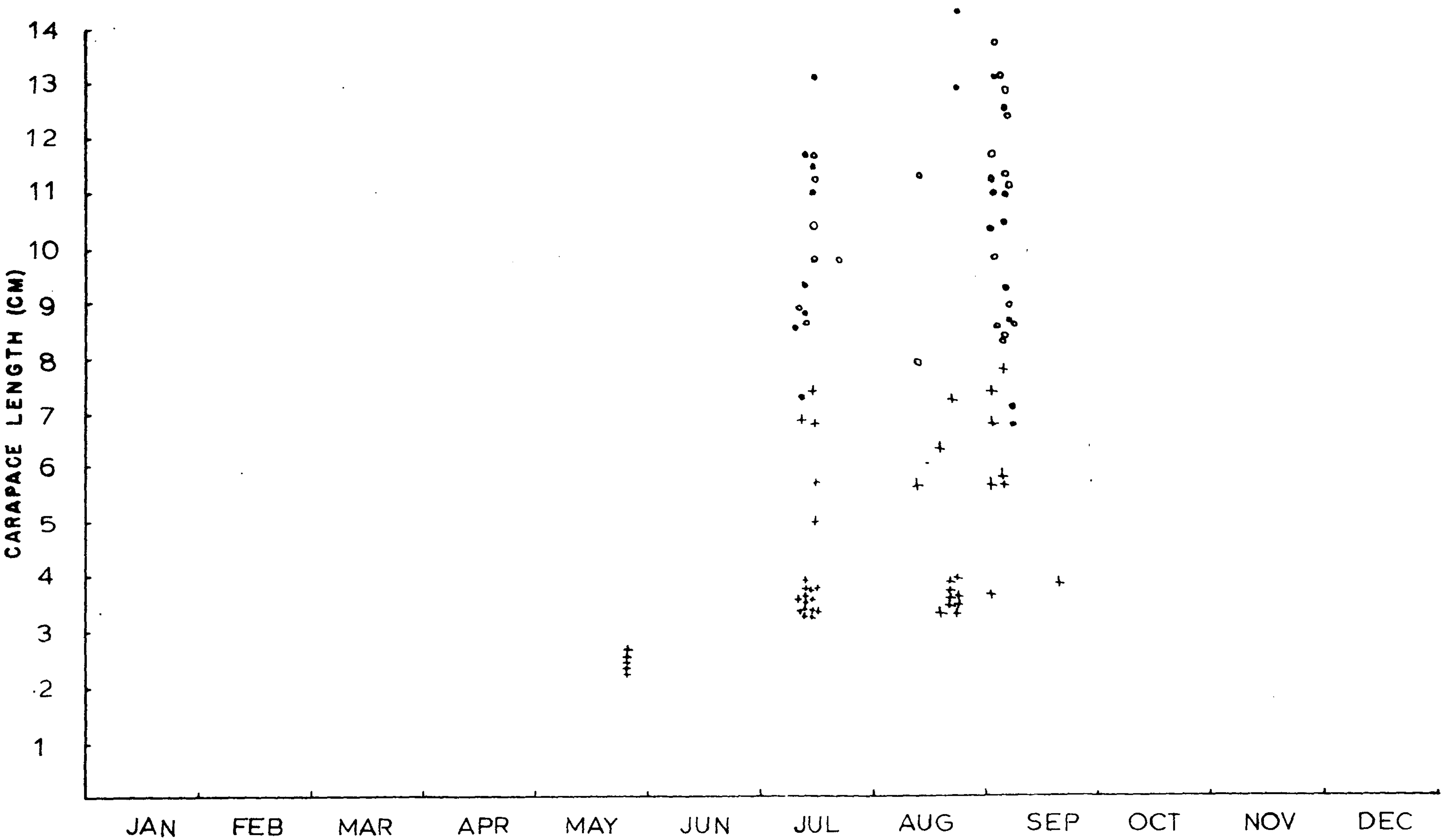

CARAPACE LENGTH (CM)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 35

The relationship between body length and date of capture for *Sternothaerus carinatus carinatus* in Oklahoma, 1956-1959. Dots = males; circles = females; crosses = juveniles.



14
13
12
11
10
9
8
7
6
5
4
3
2
1
CARAPACE LENGTH (CM)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 36

Changes of growth rate with carapace length in _Kinosternon subrubrum hippocrepis_. Rate is expressed in percentage per growing season. Broken lines indicate no data.

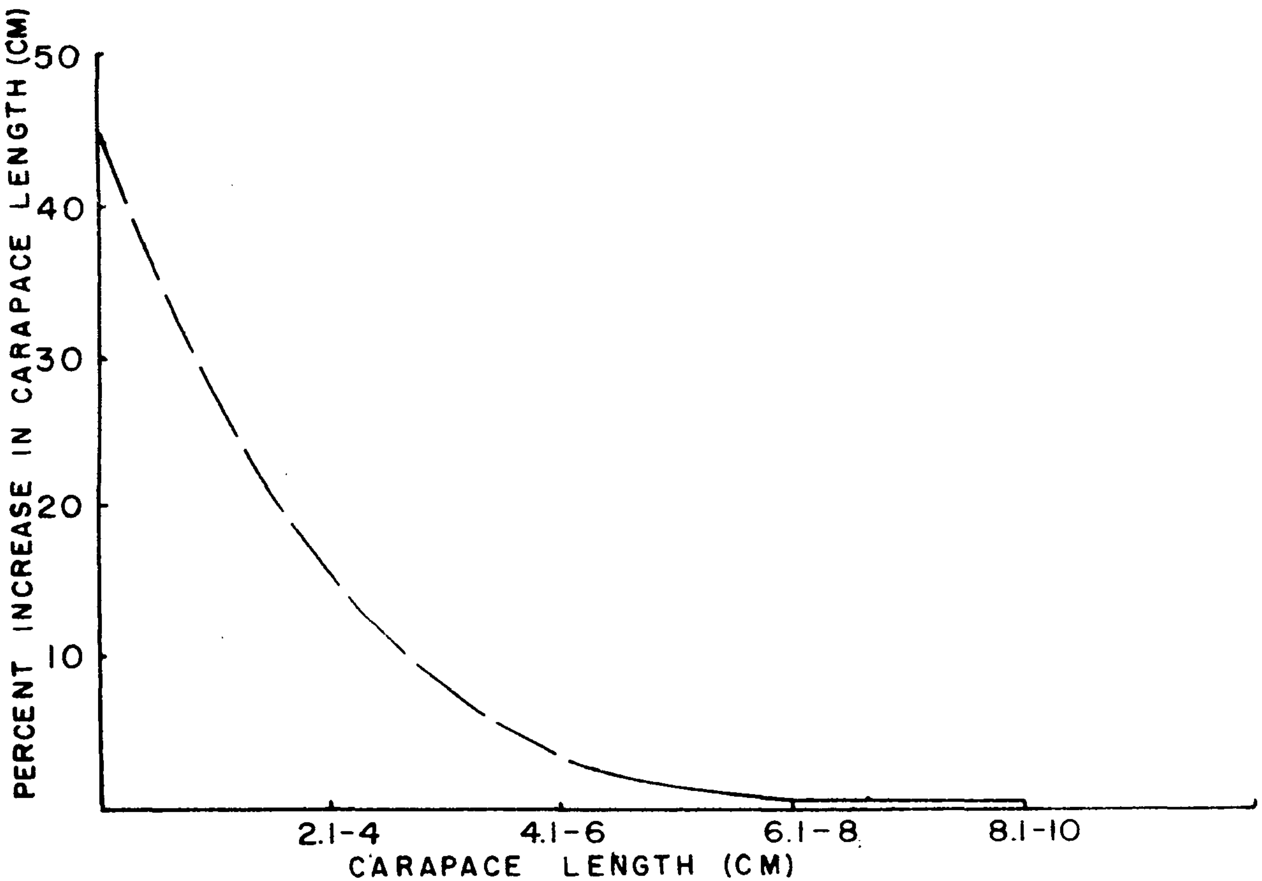

PERCENT INCREASE IN CARAPACE LENGTH (CM)
50
40
30
20
10
2.1-4
4.1-6
6.1-8
8.1-10
CARAPACE LENGTH (CM)

Figure 37

Changes of growth rate with carapace length in *Kinosternon flavescens flavescens*. Rate is expressed in percentage per growing season. Broken lines indicate no data.

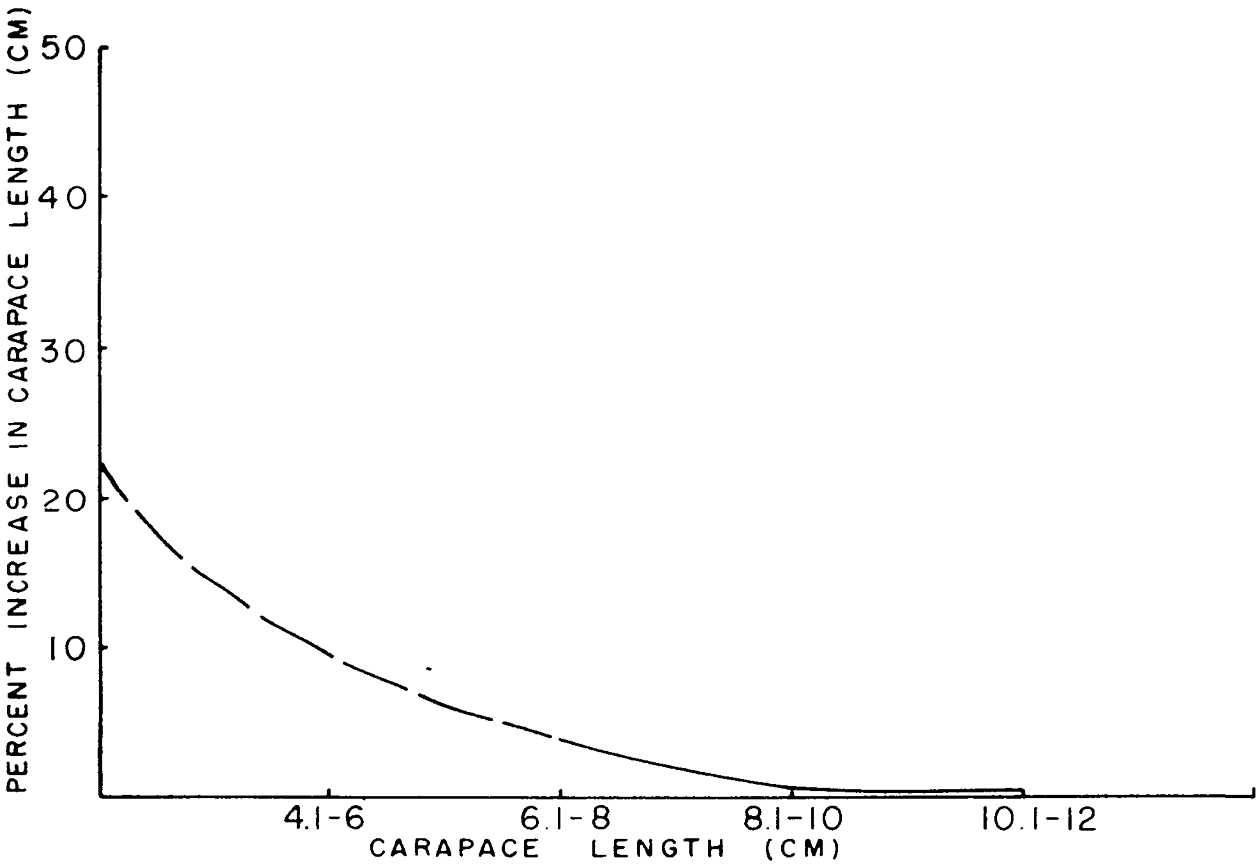

PERCENT INCREASE IN CARAPACE LENGTH (CM)
50
40
30
20
10
4.1-6
6.1-8
8.1-10
10.1-12
CARAPACE LENGTH (CM)

Figure 38

Changes of growth rate with carapace length in <u>Sternothaerus odoratus</u>. Rate is expressed in percentage per growing season. Broken lines indicate no data.

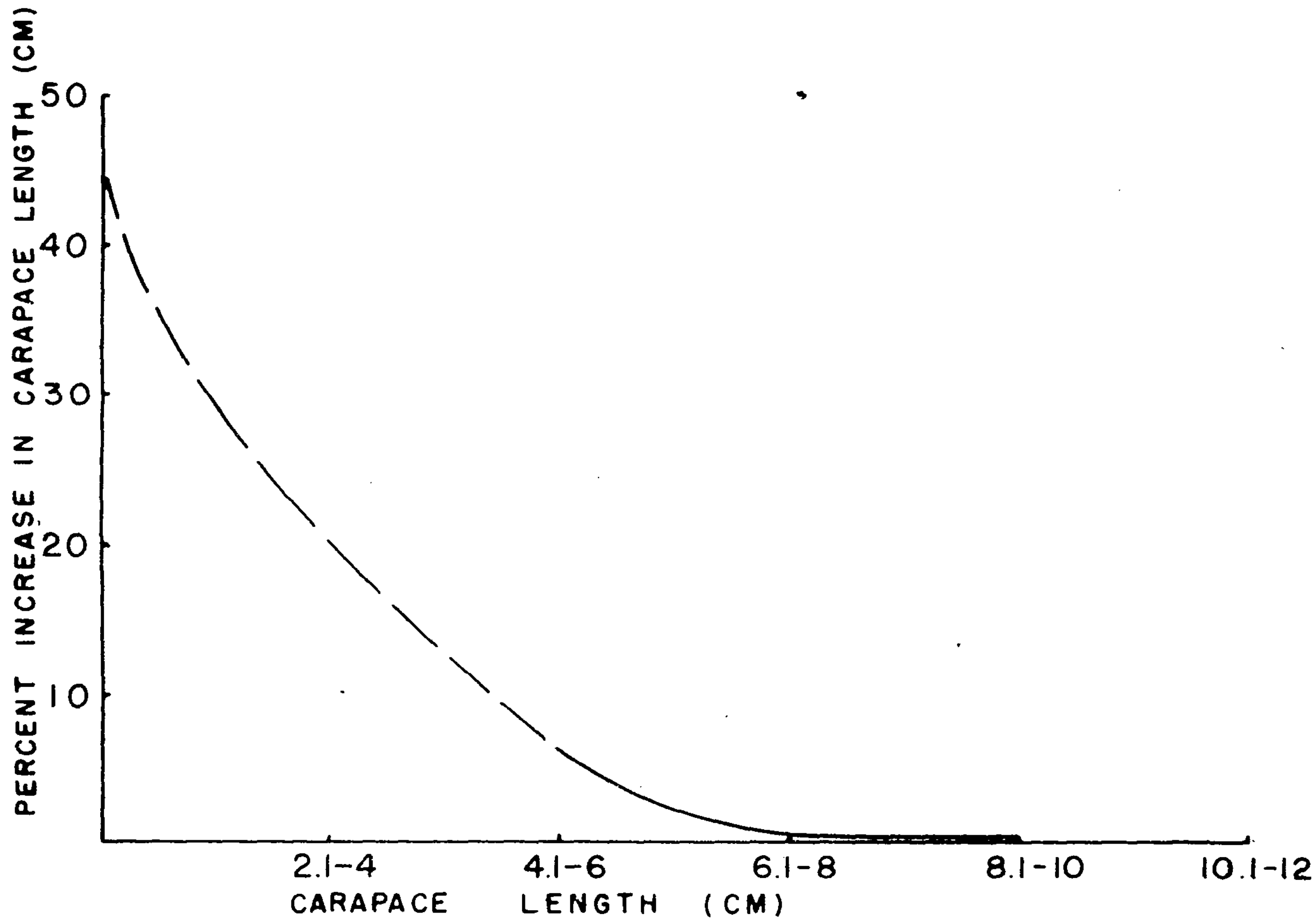
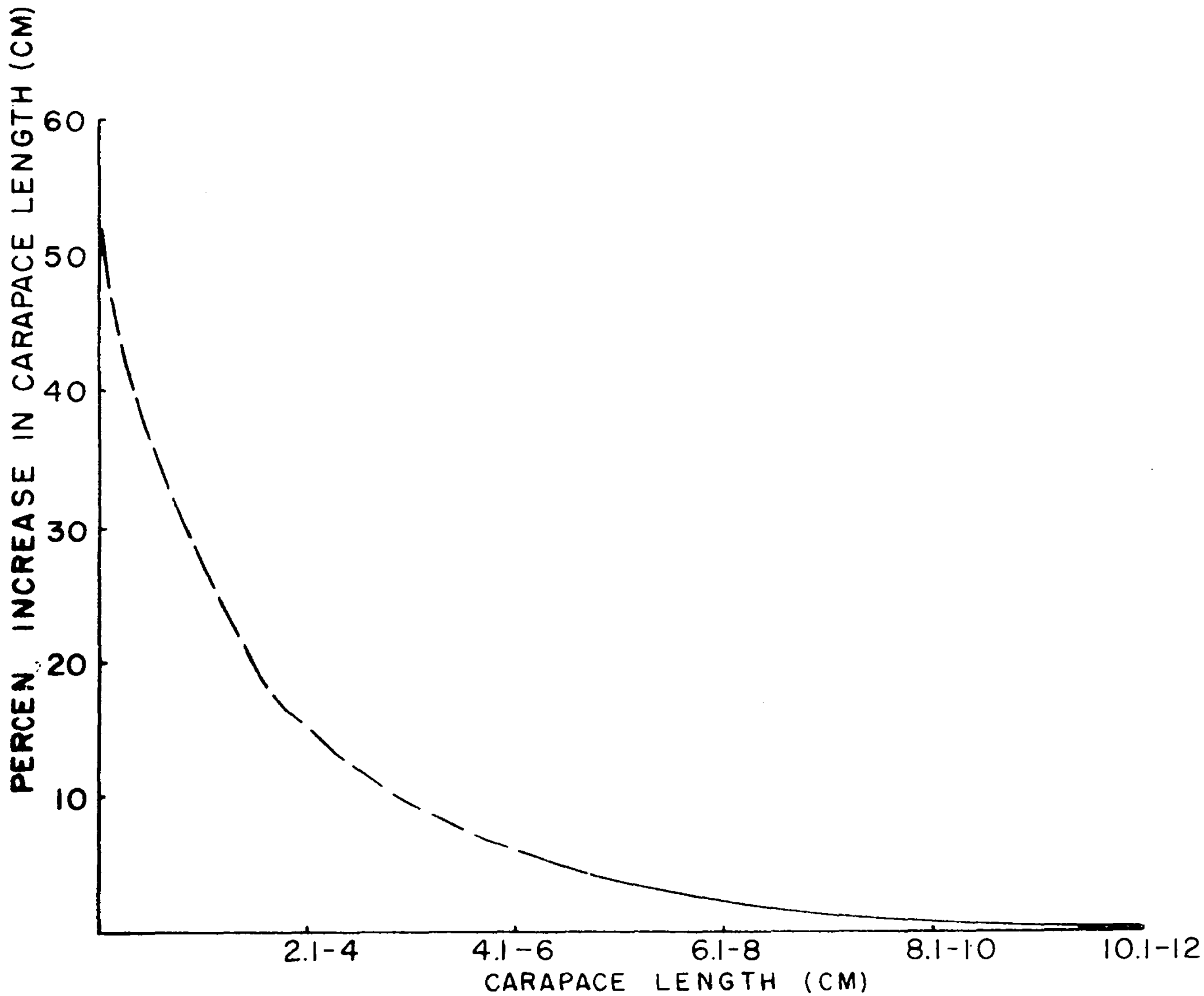

PERCENT INCREASE IN CARAPACE LENGTH (CM)
50
40
30
20
10
2.1-4
4.1-6
6.1-8
8.1-10
10.1-12
CARAPACE LENGTH (CM)

Figure 39

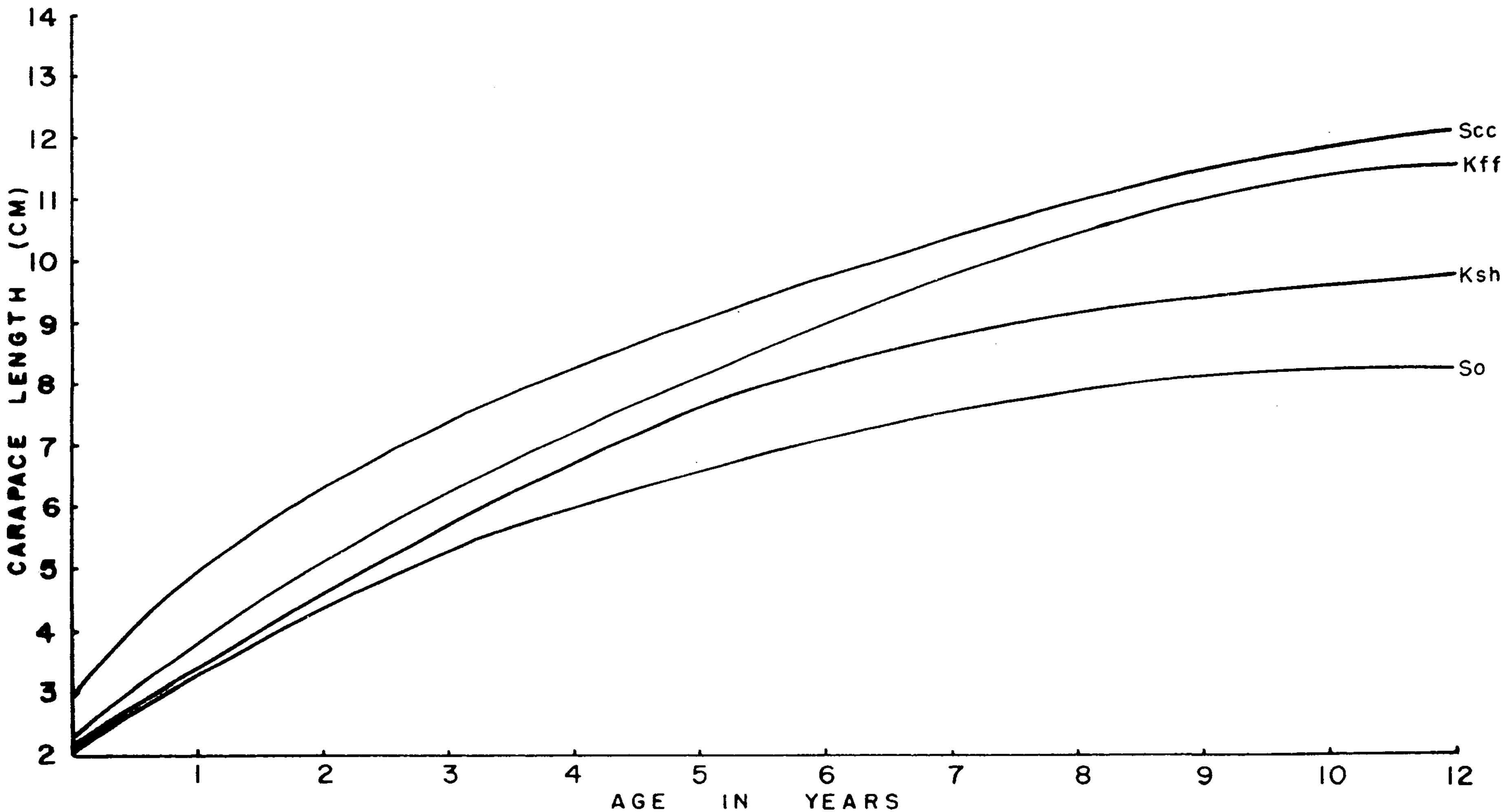
Changes of growth rate with carapace length in <u>Sternothaerus carinatus carinatus</u>. Rate is expressed in percentage per growing season. Broken lines indicate no data.



PERCENT INCREASE IN CARAPACE LENGTH (CM)
60
50
40
30
20
10
2.1-4
4.1-6
6.1-8
8.1-10
10.1-12
CARAPACE LENGTH (CM)

Figure 40

Comparative growth curves for the four kinosternid turtles in Oklahoma, by the "ring count" method.



14
13
12
11
10
9
8
7
6
5
4
3
2
CARAPACE LENGTH (CM)
1
2
3
4
5
6
7
8
9
10
12
AGE IN YEARS
Scc
Kff
Ksh
So

TABLE 7.--Growth rate for kinosternid turtles in Oklahoma, 1956-1959

Growth in carapace length for *Kinosternon subrubrum hippocrepis* in Oklahoma								
	Females				Males			
Initial carapace length in cm.	2.1-4	4.1-6	6.1-8	more than 8.1	2.1-4	4.1-6	6.1-8	more than 8.1
Number	3	4	9	31			6	17
Av. increase cm./growing season	1.66	1.37	0.26	0.038			0.030	0.083
% increase/ growing season	44%	27.5%	3.5%	.39%			1.24%	0.98%
Growth in carapace length for *Kinosternon flavescens flavescens* in Oklahoma								
Number	2	7	1	4				5
Av. increase cm./growing season	.77	.79	.31	.027				0
% increase/ growing season	22%	16.5%	4.5%	0.3%				0%

TABLE 7.--Continued

	Females				Males			
Growth in carapace length for *Sternothaerus odoratus* in Oklahoma								
Initial carapace length in cm.	2.1-4	4.1-6	6.1-8	more than 8.1	2.1-4	4.1-6	6.1-8	more than 8.1
Number		1	18	5		1	16	15
Av. increase cm./growing season		2.66	0.088	.023		1.21	.16	.078
% increase/ growing season		52%	1.3%	.25%		21%	12.80%	.96%
Growth in carapace length for *Sternothaerus carinatus carinatus* in Oklahoma								
Number	3	3	1				3	
Av. increase cm./growing season	1.27	1.30	1.53				.02	
% increase/ growing season	42.3%	37.3%	21%				.18%	

CHAPTER VII

SEASONAL PERIODICITY

There was considerable variation in the seasonal periodicity of the four species, which was correlated with their thermo-activity range.

Species	Annual Activity Period (in days)	Observed Thermo-activity Range (in °C)
K. s. hippocrepis	265	16 to 36
K. f. flavescens	140	18 to 32
S. odoratus	330	10 to 34
S. c. carinatus	310	14 to 34

The broader thermo-activity range, the longer the annual period of activity and vice versa. *S. odoratus* had the broadest thermo-activity range and was active over a longer period of each year, showing some sporadic inactivity from December through February. *S. c. carinatus* was inactive from December through February (about 55 days). Traps set in Honey Creek and Mountain Fork River, when the water temperatures were below their respective thermo-activity ranges, captured no S. odoratus or S. c. carinatus.

The hibernacula of S. odoratus and S. c. carinatus consisted of cavities beneath overhanging banks of rivers as well as beneath rocks in the river bottoms. On several occasions individuals of these species were observed entering these retreats. No evidence for aestivation was observed in these two forms. This is probably because they are able to retire to deeper and cooler water when the surface water temperature exceeds the maximum of their thermo-activity range.

K. s. hippocrepis disappeared during late October and remained secluded until early April of the following year, although sporadic activities in this species were observed during the winter months.

In Cowan Creek, the hibernacula of seven K. s. hippocrepis consisted of cavities dug by each turtle four to six inches down in the soft mud or sand of the creek bottom. The cloacal temperatures of these turtles ranged between 4.00°C and 6.00°C.

Carpenter (unpublished data) found 13 hibernating K. f. flavescens in the Oliver Wildlife Preserve. These turtles had usually dug down into natural depressions such as small gullies and old "stumpholes" beneath or near the cover of shrubs, brush piles, logs, and leaf litter, or in areas of loose sandy soil. In the present study, two K. f. flavescens were taken from a muskrat hole at the edge of Berry's Pond.

Traps set in water below 18°C and 16°C yielded no K. f. flavescens or K. s. hippocrepis respectively.

No aestivating K. s. hippocrepis was observed. K. f. flavescens was the only one of the four species which was known to aestivate. In Donita's Pond, Berry's Pond and the Oliver Wildlife Preserve, several traps were set during the months of August and September, but no turtles were caught, indicating possible aestivation in this species. Carpenter (unpublished data) found 20 aestivating K. f. flavescens at the Oliver Wildlife Preserve at a depth between 5 and 20 inches, in cavities similar to those used for hibernation. During August of 1958, eight K. f. flavescens were found aestivating in the bottom of a recently dried-up pond. They were in soft mud at a depth between 4 and 8 inches.

No significant difference was found between water temperatures taken during May, June and July, from Donita's Pond, Berry's Pond and the Oliver Wildlife Preserve, and those taken during August and September, suggesting that temperature was not a factor in stimulating aestivation behavior.

When individuals of the four species were kept in suitable water temperatures in captivity, they were active continuously over the entire year. Periods of inactivity in these turtles were thus apparently not inherent, but were a response to environmental conditions.

CHAPTER VIII

FEEDING HABITS

Fecal analysis, direct field observations and stomach and/or intestinal analyses were the methods used to study the feeding habits of the four species. The feeding records obtained from the summer of 1956 through the spring of 1960 were: 216 *K. s. hippocrepis*, 115 *K. f. flavescens*, 93 *S. odoratus*, and 43 *S. c. carinatus* (tables 8-11).

Frequently these turtles, especially *K. f. flavescens* and *K. s. hippocrepis*, defecated when captured or were induced to do so when the cloacal temperature was taken. These feces were preserved in small vials and brought to the laboratory for analysis. Stomach and/or intestinal analyses were conducted shortly after capture.

Field data indicated that the four species were primarily ouryphagous and omnivorous and their selection was related to the availability of certain foods. Turtle size was a factor in influencing the feeding habits in the four species (tables 8-11). Turtles under 5 cm in carapace length fed predominantly on small aquatic insects, algae, and carrion. Those individuals of the two species of *Kinosternon* above 5 cm in carapace length showed a preference for larger food items such as clams, snails, tadpoles, etc., although they appeared to take any size food available to them. *Sternothaerus* above 5 cm in carapace length showed a preference for molluscs. Tinkle (1958) in his study of the *S. carinatus* complex stated that those turtles change their feeding habits from insectivorous to molluscivorous when they become adult.

Seasonal changes in the feeding habits were observed for both species of *Sternothaerus*. During the summer months these species fed predominantly on animals, while during the winter months algae and aquatic seed plants were the main food items.

Laboratory and field observations indicated that *Kinosternon* had more adequate senses of smell and sight in detecting prey than Sternothaerus. Cagle and Chaney (1950) and Tinkle (1958) reported that it was hard to trap *S. c. carinatus* even if they were common in an area. In a concrete tank which was five feet long and two feet wide, liver was introduced at one end of the tank while the turtles were at the other end. In 31 trials, K. f. flavescens was the first to detect the presence of this food by swimming toward the liver. K. s. hippocrepis and S. odoratus were next in that order, while S. c. carinatus usually remained passive, eventually swimming toward the liver.

On May 5, 1957, 31 K. f. flavescens were collected from an area two miles east of Cherokee, Oklahoma. The next day thousands of Conchostracidae were found in the turtles' feces indicating that they had been eating these minute crustaceans.

K. f. flavescens were seen on several occasions in the Oliver Wildlife Preserve feeding on eggs of Ambystoma texanum which were scattered along the edges of and clinging to submerged sticks in the pools.

On June 4, 1959, approximately 30 K. f. flavescens were observed feeding on tadpoles in a small water-filled depression near a pond in the Oliver Wildlife Preserve. When the observer appeared, these turtles retreated into the pond. The depression was about five feet in diameter with water two inches in depth. The number of tadpoles in the depression was estimated to have been 300.

In Cowan Creek, on several occasions, K. s. hippocrepis were seen foraging in pig and cow dung, often taking kernels of corn from the dung. Where the water depth was half an inch to three inches, they were observed walking in the shallow creek searching in the mud along the edge of the creek, less frequently in the middle of the creek. Sometimes they would submerge in deep holes of water, investigating the mud, or resting at the bottom of the creek headed into the current, perhaps waiting for some article of food to float by them.

To test the ability of the four species to catch relatively fast-moving prey, the following experiment was repeated 7 times using each time 100 living and 100 dead tadpoles. These were introduced to 5 individuals of each of the four species. Approximately 80 percent of the tadpoles taken by K. f. flavescens and 65 percent taken by K. s. hippocrepis were living, while all the tadpoles eaten by S. odoratus and S. c. carinatus were dead and these turtles did not attempt to capture the living ones. S. odoratus and S. c. carinatus appeared to be slower in their movements than K. f. flavescens and K. s. hippocrepis. Perhaps the slow movement was also related to the predominantly molluscivorous habit of Sternothaerus.

In the laboratory, K. f. flavescens was much faster than K. s. hippocrepis in capturing live frogs, toads, crayfish, salamanders, and small snakes.

Feeding occurred at any time when the turtles were active in the diel cycle. K. f. flavescens and K. s. hippocrepis were observed to start feeding soon after they emerged from hibernation. S. odoratus and S. c. carinatus were active in winter and fed over most of the year.

K. s. hippocrepis and K. f. flavescens which were hatched in the laboratory accepted food a few hours after hatching.

All four species, especially the Sternothaerus, were bottom feeders. Frequently the turtles of the four species were observed walking, with their necks fully extended, along the bottom searching for food. Occasionally others were observed feeding at the surface and while swimming. Fishermen take these turtles regularly with their baited hooks. These turtles were also observed "poking" their heads into soft mud, sand, and decaying plant material, apparently searching for food.

Fresh bait was necessary to attract these turtles to traps, whereas Pseudemys and Graptemys were attracted to decaying bait.

TABLE 8.--Field records of food items taken by *Kinosternon subrubrum hippocrepis*

(X = food items unable to identify specifically)

Method of obtaining data	No. of turtles examined	Carapace length	Food Items: Insecta	Crustacea	Mullasca	Amphibia	Carrion	Plant Material
feces analysis	7	under 5 cm.	X (90%)					10%
feces analysis	178	over 5 cm.	Dragon fly (larvae) Blister beetle Hydro-phylidae odanata (25%)		*Physa* (55%)			corn kernels algae (20%)
direct observa-tion	20	over 5 cm.	X (20%)					algae, corn kernels (80%)
stomach & intestinal analysis	13	over 5 cm.	X (20%)		X (80%)			

TABLE 9.--Field records of food items taken by *Kinosternon flavescens flavescens*

(X = food items unable to identify specifically)

Method of obtaining data	No. of turtles examined	Carapace length	Food Items: Insecta	Crustacea	Mullasca	Amphibia	Carrion	Plant material
feces analysis	7	under 5 cm.	X (100%)					
feces analysis	5	under 5 cm.	X (80%)				X (20%)	
feces analysis	58	over 5 cm.	May fly (larvae) Dragon fly (.5%)	Conchas-tracods (50%)	*Physa* Helisoma (45%)	Tadpoles (5%)	X (.5%)	
stomach & intestinal analysis	5	over 5 cm.	X (5%)		*Physa* Helisoma		X (5%)	
direct observation	40	over 5 cm.				Amhystoma texanum (eggs) Tadpoles		

TABLE 10.--Field records of food items taken by *Sternothaerus odoratus*

(X = food items unable to identify specifically)

Method of obtaining data	No. of turtles examined	Carapace length	Food Items: Insecta	Crustacea	Mullasca	Carrion	Plant material
feces analysis	15	under 5 cm.	X (100%)				
feces analysis	45	over 5 cm.	odanata (larvae) Pytis-cidae (larvae) Coenagri-onidae nymph Diptera (67%)	Creyfish (7%)	*Physa* (19%)		X algae (7%)
stomach & intestinal analysis	12	over 5 cm.	X (20%)			X (30%)	X (50%)
direct observation	6	over 5 cm.	X			X	X

TABLE 11.--Field records of food items taken by <u>Sternothaerus carinatus carinatus</u>

(X = food items unable to identify specifically)

Method of obtaining data	No. of turtles examined	Carapace length	Food Items: Insecta	Crustacea	Mullasca	Amphibia	Carrion	Plant material
feces analysis	11	under 5 cm.	X (100%)					
stomach analysis	2	under 5 cm.	(10%)					algae (90%)
direct observation	7	under 5 cm.	X % ?					X % ?
feces analysis	3	over 5 cm.			clams snails (90%)			algae (10%)
stomach & intestinal analysis	19	over 5 cm.	X		Physa Helesoma (90%)		X (10%)	
direct observation	1	over 5 cm.					X dead fish	

CHAPTER IX

POPULATION

The population composition of each study area was determined relative to size groups and sex ratio (tables 12-15 and figs. 41-48). Sex determination was limited to individuals measuring approximately four centimeters or greater, the length at which sexually dimorphic characters become apparent.

Sexual maturity was determined by the examination of the gonads. Sexually mature males had active sperm. Female maturation was recorded when the size of the ovarian follicles exceeded one centimeter in diameter. Using the above method, the attainment of sexual maturity varied in its size-age relationship for the four species.

Species	Carapace length in cm		Estimated Age in Years	
	Male	Female	Male	Female
K. s. hippocrepis	7.50	9.00	5	8
K. f. flavescens	10.00	11.00	8	10
S. odoratus	7.00	7.60	5	8
S. c. carinatus	10.98	11.00	6	7.8

Sexual maturity was reached earlier in males than in females, and individuals of K. s. hippocrepis and S. odoratus reached this state at a smaller size and at a younger age than S. c. carinatus and K. f. flavescens. Mature individuals captured in the eight separate populations (figs. 41-48) far exceeded the immature individuals in number, the juveniles representing only a small segment of the populations.

Sex ratios for mature K. s. hippocrepis were 47 males to 62 females in Cowan Creek, 16 males to 24 females at the Tishomingo Fish Hatchery.

For mature K. f. flavescens the sex ratios of males to females were 23 to 35 in Berry's Pond and 64 to 88 in the Oliver Wildlife Preserve. In Donita's Pond the number of mature K. f. flavescens males exceeded that of the females by 20 to 13.

The sex ratio for mature S. odoratus was 118 males

Species	Carapace length in cm		Estimated Age in Years	
	Male	Female	Male	Female
K. s. hippocrepis	7.50	9.00	5	8
K. f. flavescens	10.00	11.00	8	10
S. odoratus	7.00	7.60	5	8
S. c. carinatus	10.98	11.00	6	7.8

Sexual maturity was reached earlier in males than in females, and individuals of *K. s. hippocrepis* and *S. odoratus* reached this state at a smaller size and at a younger age than *S. c. carinatus* and *K. f. flavescens*. Mature individuals captured in the eight separate populations (figs. 41-48) far exceeded the immature individuals in number, the juveniles representing only a small segment of the populations.

Sex ratios for mature *K. s. hippocrepis* were 47 males to 62 females in Cowan Creek, 16 males to 24 females at the Tishomingo Fish Hatchery.

For mature *K. f. flavescens* the sex ratios of males to females were 23 to 35 in Berry's Pond and 64 to 88 in the Oliver Wildlife Preserve. In Donita's Pond the number of mature *K. f. flavescens* males exceeded that of the females by 20 to 13.

The sex ratio for mature *S. odoratus* was 118 males to 115 females.

The sex ratio for mature *S. c. carinatus* was 36 females to 22 males.

Chi square was used to test the significance of the deviation of the sex ratio from an expected 50-50 ratio.

The following table summarizes the result of Chi square calculations for turtles from the eight areas:

Place	Species	Sex ratio males:females	Chi square	Probability
Cowan Creek	*K. s. hippocrepis*	57:62	2.0652	$P > .10$
Lake Texoma	*K. s. hippocrepis*	16:28	3.2726	$P > .05$
Tishomingo	*K. s. hippocrepis*	16:25	1.6000	$P > .80$
Berry's Pond	*K. f. flavescens*	23:35	2.4826	$P > .10$
Oliver Wildlife Preserve	*K. f. flavescens*	64:28	3.7894	$P > .05$
Donita's Pond	*K. f. flavescens*	20:13	1.5312	$P > .20$
Honey Creek	*S. odoratus*	118:116	.0386	$P > .80$
Mountain Fork River	*S. c. carinatus*	22:36	3.3792	$P > .05$

The above results indicate that mature females are more abundant than mature males in all species but S. odoratus.

One male of K. f. flavescens was kept with several females of the same species in a concrete tank and was observed copulating with several different females, indicating polygamy.

Population Estimate

By using the release and recapture technique, several methods were adopted for population estimates.

The Lincoln Index (Lincoln, 1930) was used to estimate the populations at the four areas studied (Cowan Creek, Honey Creek, Berry's Pond, and Mountain Fork River). By comparing the samplings over two different periods the population was estimated from the following equation:

$$\frac{\text{Population in 1956 (X)}}{\text{Number of marked animals in 1956.}} = \frac{\text{Number of animals captured in 1957.}}{\text{Number marked in 1956 and recaptured in 1957.}}$$

The method of Hayne (1949), which is a modification of the Lincoln Index, was also used. Hayne, in describing his method said,

> As marking of the animals progresses, the proportion of the population which is marked will increase. Marking one additional animal will cause the proportion marked to increase by a certain amount, and this

> increase is inversely proportional to the population number. After finding the average amount by which the marking of one further animal changes the proportion of the population which is marked, it is easy to estimate the population.

Hayne expresses "the proportion of the population" for the entire period of sampling by the following equation:

$$Y = \frac{X}{P}$$

where Y = the proportion of the population marked; X = number of individuals previously marked and released into the population; P = Population.

The formula for Hayne's method was:

$$P = \frac{wx^2}{wxy}$$

where x, y, and P have the same meaning as above; w = the number of marked and unmarked animals caught in each sample.

To obtain the proportion of the marked turtles caught at each visit to the area, the following formula may be used:

$$Yi = \frac{Mi}{Wi} \text{ or } YiWi = Mi$$

Yi is the proportion of the individuals caught in a certain trip; Mi = number of marked caught on that trip; Wi = number of individuals (marked and unmarked) caught on that trip (table 16).

Since YiWi = MiXi

Multiply both sides of the equation by Xi to obtain:

WiY iXi = MiXi

therefore

wyz - mx

and

$$P = \frac{wx^2}{mx} = \frac{WX^2}{wxy}$$

In using Hayne's and the Lincoln Index methods, the sampling period was limited to one growing season (table 16).

In using the Lincoln Index and Hayne's methods, the following assumptions should be made:

1. When marked individuals are released into the population, they should be distributed in such a way that the probability of capturing marked and unmarked individuals is uniform.

2. During the period of sampling the population must be stable. Mortality and natality should be in equal proportion among marked and unmarked individuals.

3. There should be equal time and effort spent throughout the sampling area.

4. The method of marking should not affect the

behavior of the animals in such a way as to make it easier or harder to collect the marked than the unmarked individuals.

The above assumptions, with the exception of the third one, were fitting for the situations in the four populations. The degree of immigration, emigration, and the rate of natality, mortality were unknown. Traps set in peripheral regions to the study areas revealed the marked specimens.

The results of the two methods used for population estimate showed considerable variation (table 17). This was due to the difference in the proportion of captures and recaptures during each sampling period. Since Hayne's method was suggested to estimate a population with a rapid turnover in a short period it is felt that using Lincoln Index for a long sampling period gave greater accuracy, for population turnover is slow in turtles.

The population density is commonly estimated by dividing the size of the area sampled by the number of the individuals in that area. Since there was a considerable variation in the population estimate due to the period of sampling and the method of estimation (table 17), the population density also varied.

A total of 33 turtles from Donita's Pond and 34 turtles from the Oliver Wildlife Preserve were captured. The former area is about one acre in size and the latter one is about 1,000 square feet. The investigator thought that all or most of the turtles from the above areas were captured.

Figure 41

Population composition of <u>Kinosternon subrubrum hippocrepis</u> of various carapace lengths at Cowan Creek, Marshall County, Oklahoma, 1956-1959. Dots = males; no dots = females; lines = juveniles.

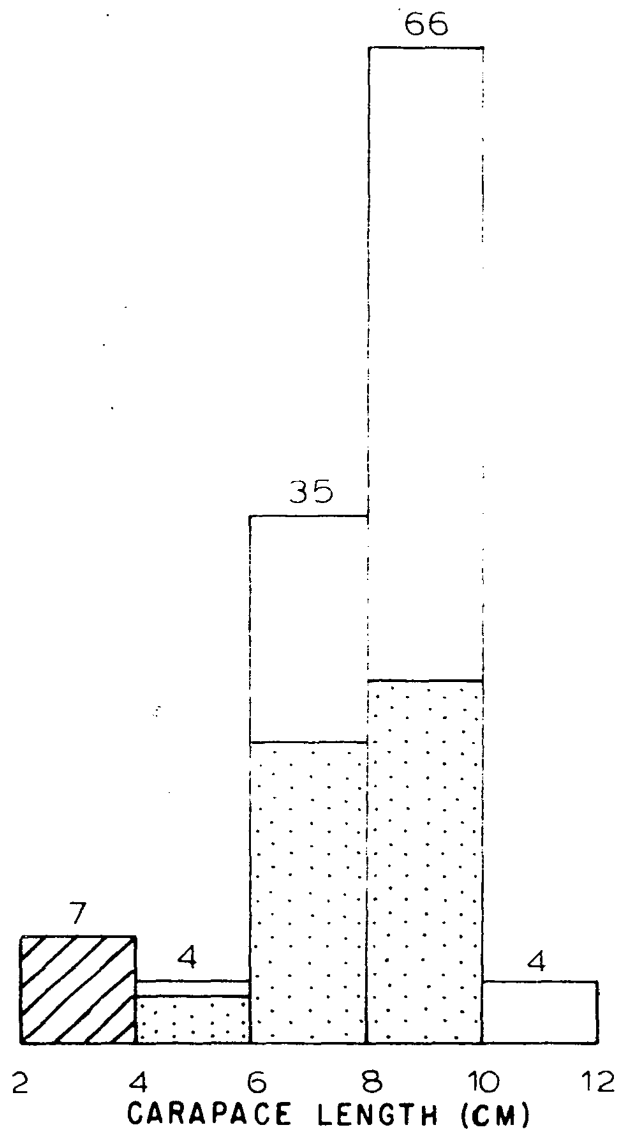
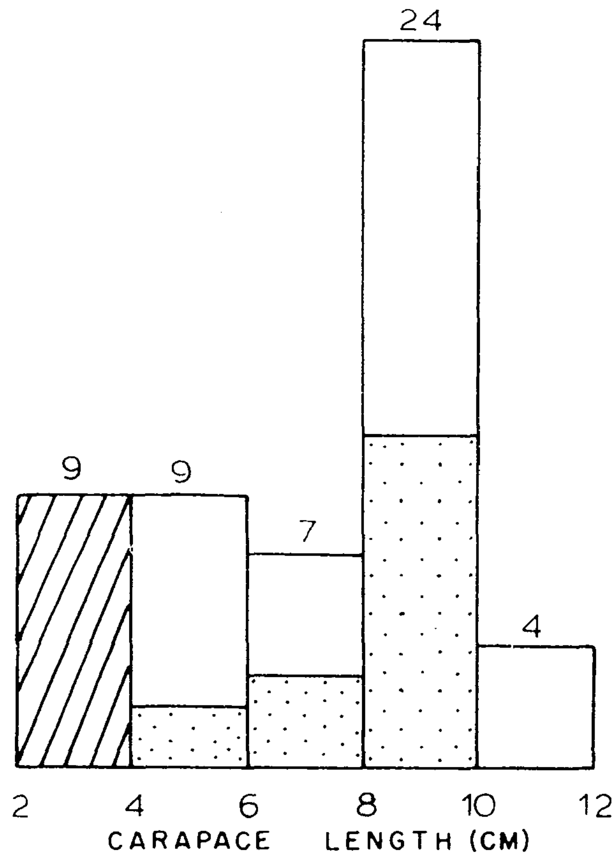

66
35
7
4
4
2
4
6
8
10
12
CARAPACE LENGTH (CM)

Figure 42

Population compositión of <u>Kinosternon</u> <u>subrubrum</u> <u>hippocrepis</u> of various carapace lengths at Lake Texoma, Marshall County, Oklahoma, 1957-1959. Dots = males; no dots = females; lines = juveniles.



24
9
9
7
4
2
4
6
8
10
12
CARAPACE LENGTH (CM)

Figure 43

Population composition of *Kinosternon subrubrum hippocrepis* of various carapace lengths at Tishomingo Fish Hatchery, Johnston County, Oklahoma, 1956-1959. Dots = males; no dots = females; lines = juveniles.

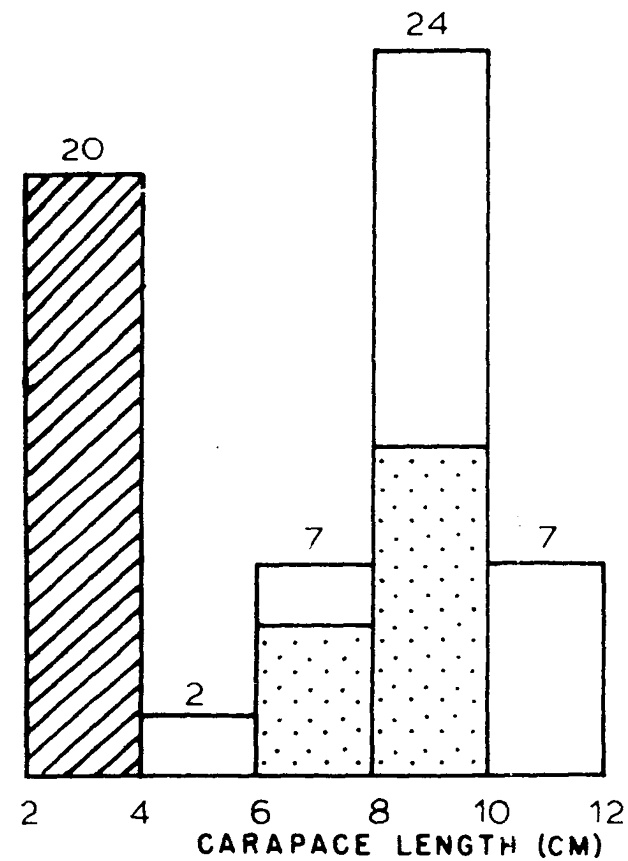
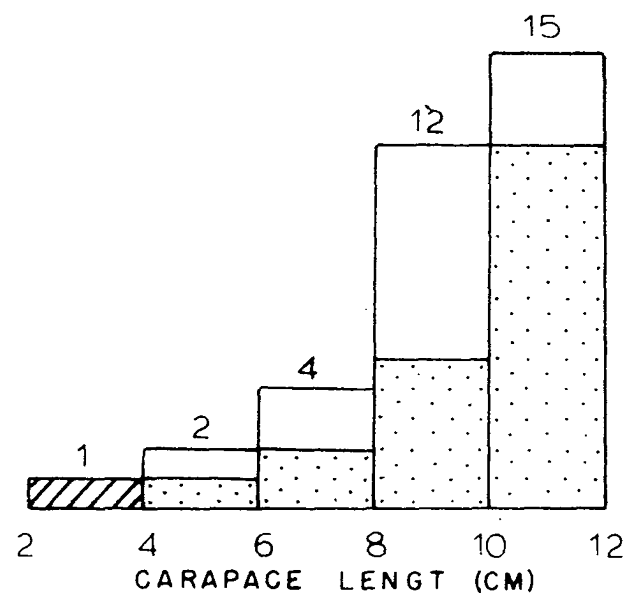

20
2
7
24
7
2
4
6
8
10
12
CARAPACE LENGTH (CM)

Figure 44

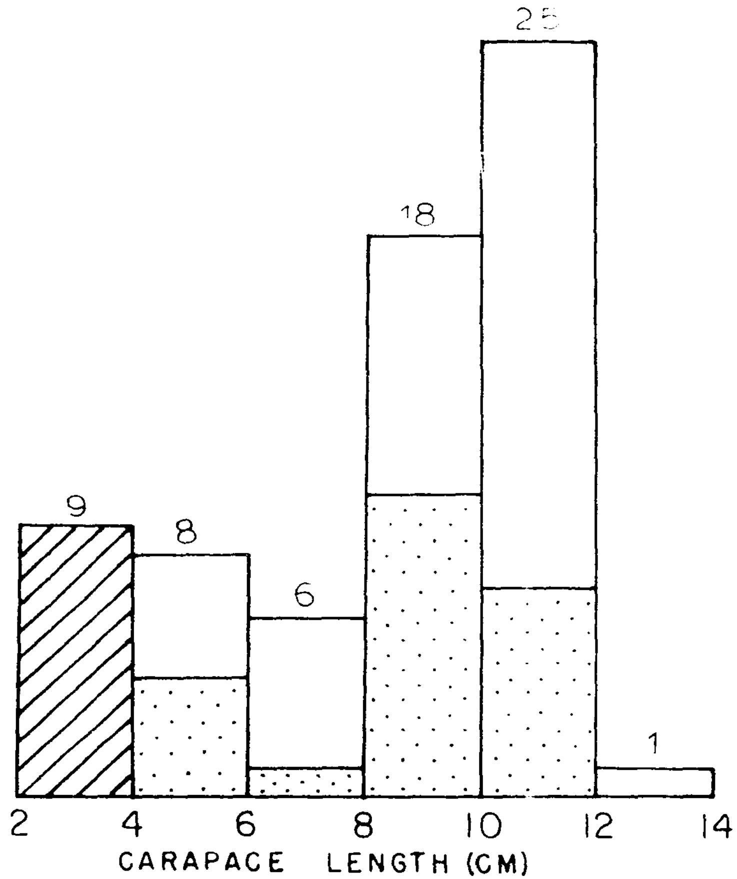
Population composition of _Kinosternon flavescens flavescens_ of various carapace lengths at Donita's Pond, Garfield County, Oklahoma, 1959. Dots = males; no dots = females; lines = juveniles.



15
12
4
2
1
2
4
6
8
10
12
CARAPACE LENGT (CM)

Figure 45

Population composition of *Kinosternon flavescens flavescens* at various carapace lengths at Beny's Pond, Cleveland County, Oklahoma, 1958-1959. Dots = males; no dots = females; lines = juveniles.



9
8
6
18
25
1
2
4
6
8
10
12
14
CARAPACE LENGTH (CM)

Figure 46

Population composition of *Kinosternon flavescens flavescens* of various carapace lengths at the Oliver Wildlife Preserve, Cleveland County, Oklahoma, 1954-1959. Dots = males; no dots = females; lines = juveniles.

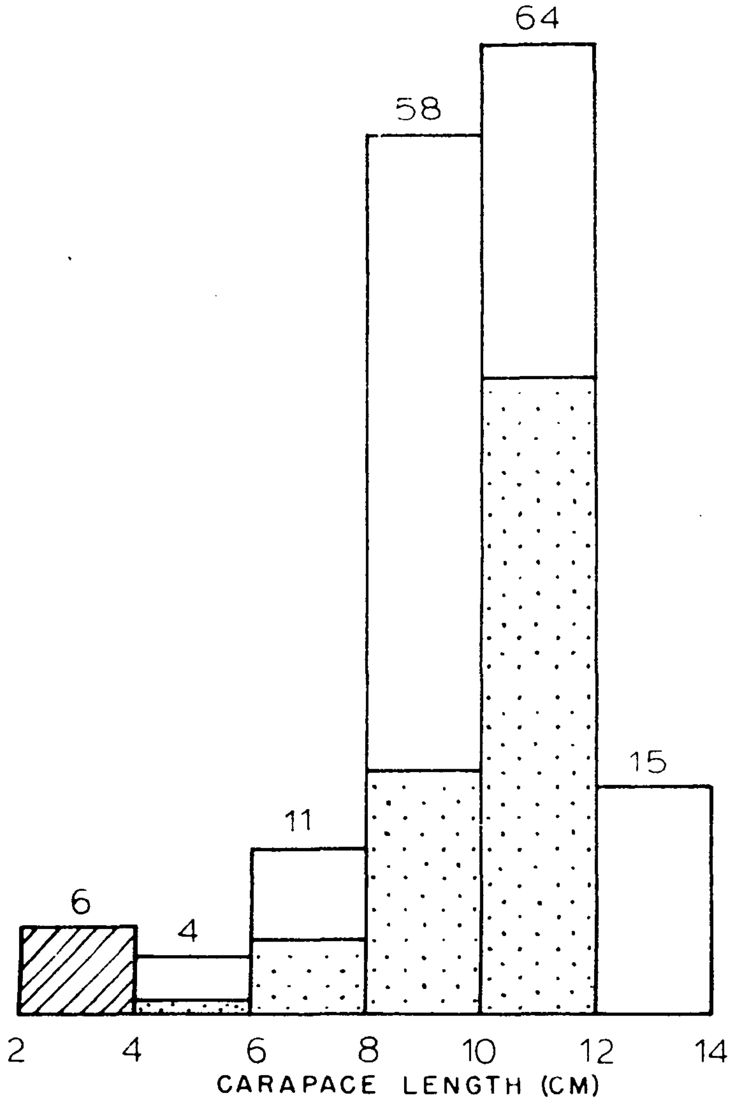

64
58
15
11
6
4
2
4
6
8
10
12
14
CARAPACE LENGTH (CM)

Figure 47

Population composition of *Sternothaerus odoratus* of various carapace lengths at Honey Creek, Murray County, Oklahoma, 1957-1959. Dots = males; no dots = females; lines = juveniles.

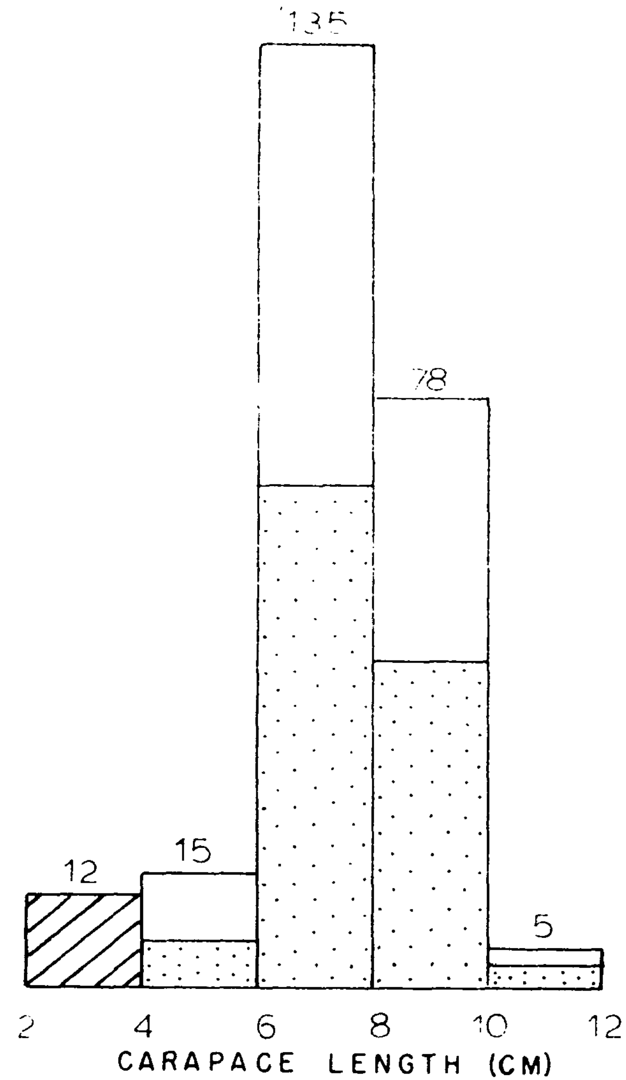

135
78
12
15
5
2
4
6
8
10
12
CARAPACE LENGTH (CM)

Figure 48

Population composition of _Sternothaerus carinatus carinatus_ of various carapace length at Mountain Fork River, McCurtain County, Oklahoma, 1957-1959. Dots = males; no dots = females; lines = juveniles.

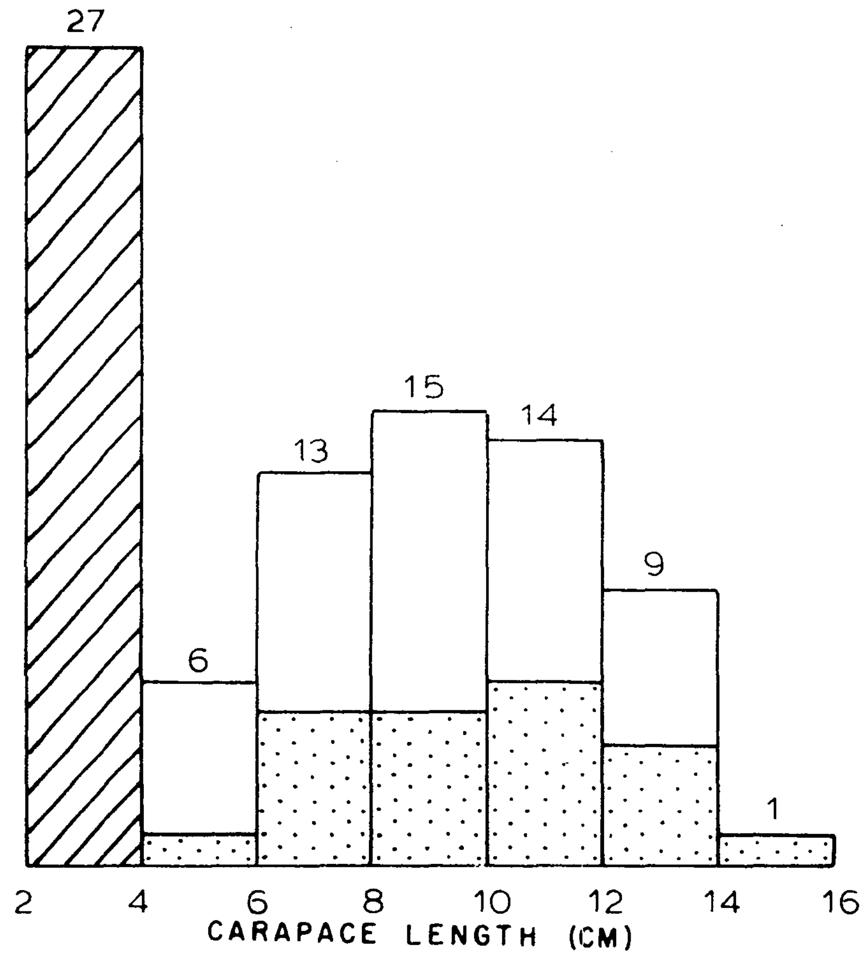

27
6
13
15
14
9
1
2
4
6
8
10
12
14
16
CARAPACE LENGTH (CM)

TABLE 12.--Sex ratios for size groups of *Kinosternon subrubrum hippocrepis* (Carapace length in cm.)

Location	2.1 - 4		4.1 - 6		6.1 - 8		8.1 - 10		10.1 - 12	
	Juvenile		N	%	N	%	N	%	N	%
Cowan	N	%	M---3	2.58	M--20	17.24	M--24	20.68	M---0	0
Creek			F--10	8.61	F--15	12.93	F--42	36.21	F---4	3.44
	7	6.03	T---4	3.44	T--35	30.17	T--66	56.89	T---4	3.44
	Juvenile		N	%	N	%	N	%	N	%
Lake	N	%	M---2	3.77	M---3	5.66	M--11	20.75	M---0	0
Texoma			F---7	13.30	F---4	7.84	F--13	24.52	F---4	7.54
Shore	9	16.98	T---9	16.97	T---7	13.30	T--24	45.27	T---4	7.54
	Juvenile		N	%	N	%	N	%	N	%
Tishomingo	N	%	M---0	0	M---5	8.33	M--11	18.34	M---0	0
Fish			F---2	3.33	F---2	3.33	F--13	21.66	F---7	11.66
Hatchery	20	33.33	T---2	3.33	T---7	11.66	T--24	40.00	T---7	11.66

N = Number F = Female
% = Percent T = Total
M = Male

TABLE 13.--Sex ratios for size groups of *Kinosternon flavescens flavescens*

(Carapace length in cm.)

Location	2.1 - 4		4.1 - 6		6.1 - 8		8.1 - 10		10.1 - 12		12.1 - 14	
	Juvenile		N	%	N	%	N	%	N	%	N	%
Berry's Pond	N	%	M---4	5.97	M---1	1.49	M--10	14.92	M---7	10.44	M---1	9.49
			F---4	5.97	F---5	7.46	F---8	11.94	F--18	26.86	F---0	0
	9	13.41	T---8	11.94	T---6	8.95	T--18	26.86	T--25	37.50	T---1	1.49
	Juvenile		N	%	N	%	N	%	N	%	N	%
Oliver's Pond	N	%	M---1	0.63	M---5	3.16	M--16	10.12	M--42	26.58	M---0	0
			F---3	1.90	F---6	3.79	F--42	26.58	F--22	13.92	F--15	9.45
	6	3.79	T---4	2.53	T--11	6.95	T--58	36.70	T--64	40.50	T--15	9.45
	Juvenile		N	%	N	%	N	%	N	%	N	%
Donita's Pond	N	%	M---1	2.98	M---2	5.88	M---5	14.70	M--12	35.29	M---0	0
			F---1	2.98	F---2	5.88	F---7	20.58	F---3	8.82	F---0	0
	1	2.98	T---2	5.96	T---4	11.76	T--12	35.28	T--15	44.11	T---0	0

N = Number
% = Percent
M = Male
F = Female
T = Total

TABLE 14.--Sex ratios for size groups of *Sternothaerus odoratus*

(Carapace length in cm.)

Location	2.1 - 4		4.1 - 6		6.1 - 8		8.1 - 10		10.1 - 12	
	Juvenile		N	%	N	%	N	%	N	%
	N	%	M---6	2.45	M--66	26.94	M--43	17.55	M---3	1.22
Honey Creek			F---9	3.67	F--69	28.16	F--35	14.28	F---2	0.82
	12	4.89	T--15	6.12	T-135	55.10	T--78	31.83	T---5	2.04

N = Number
% = Percent
M = Male
F = Female
T = Total

TABLE 15.--Sex ratios for size groups of *Sternothaerus carinatus carinatus*

(Carapace length in cm.)

Location	2.1 - 4		4.1 - 6		6.1 - 8		8.1 - 10		10.1 - 12		12.1 - 14		14.1 - 16	
	Juvenile													
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Beaver's Bend			M--1	1.17	M--5	5.88	M--5	5.88	M--6	7.05	M--4	4.70	M--1	1.17
			F--5	5.88	F--8	9.41	F-10	11.76	F--8	9.41	F--5	5.88	F--0	0
	27	31.76	T--6	7.05	T-13	15.29	T-15	17.64	T-14	16.47	T--9	10.58	T--1	1.17

N = Number
% = Percent
M = Male
F = Female
T = Total

TABLE 16.--Population estimate by the Hayne Method for four species of kinosternid turtles in Oklahoma, 1956-1959

Kinosternon subrubrum hippocrepis, 1956

Date	New		Mi		Wi		Xi		X^2i	
	M	F	M	F	M	F	M	F	M	F
June 8	1	0	0	0	1	0	0	0	0	0
June 9	2	3	0	1	2	4	1	0	1	0
June 11	0	0	0	1	0	1	3	3	9	9
June 15	0	0	0	1	0	1	3	3	9	9
June 22	0	0	0	1	0	1	3	3	9	9
June 24	1	0	0	0	1	0	3	3	9	9
June 29	1	0	0	0	1	0	4	3	16	9
August 6	0	1	0	0	0	1	5	3	25	9
August 7	1	3	0	0	1	3	5	4	25	16
August 8	0	2	0	1	0	3	6	7	36	49
August 9	0	0	0	0	0	0	6	9	36	81
August 11	0	2	0	3	0	5	6	9	36	81
August 12	5	1	0	0	5	1	6	11	36	121
August 13	1	1	0	0	1	1	11	12	121	144
August 16	2	3	0	1	2	4	12	13	144	169
August 17	0	0	0	1	0	1	14	16	196	256
August 18	0	2	0	1	0	3	14	16	196	256
August 19	2	0	2	1	4	1	14	18	196	324
August 20	0	1	2	0	2	1	16	18	196	324
August 21	1	1	0	0	1	1	16	19	256	361
August 22	0	1	0	0	0	1	17	20	289	400
August 23	0	0	1	0	1	0	17	21	289	441

TABLE 16.--Continued

Date	New M	New F	Mi M	Mi F	Wi M	Wi F	Xi M	Xi F	X^2i M	X^2i F
August 24	0	2	0	1	0	3	17	21	289	441
August 25	0	0	0	1	0	1	17	23	289	529
August 27	1	0	0	0	1	0	17	23	289	529
August 28	0	1	0	1	0	2	18	23	324	529
August 29	2	1	0	2	2	3	18	24	324	576
August 30	0	1	0	1	0	2	20	25	400	625
September 1	0	1	0	1	0	2	20	26	400	676
September 2	3	0	1	0	4	0	23	27	529	729
September 4	0	0	0	1	0	1	23	27	529	729
Kinosternon subrubrum hippocrepis, 1957										
June 8	0	1	0	0	0	1	0	0	0	0
June 14	1	0	0	0	1	0	0	0	0	0
June 15	1	4	0	0	1	4	1	1	1	1
June 16	0	4	1	0	1	4	2	5	4	25
June 17	0	0	0	2	0	2	2	9	4	81
June 18	3	0	0	4	3	4	2	9	4	81
June 19	0	2	0	3	0	5	5	9	25	81
June 30	1	0	1	1	2	1	5	11	25	121
July	0	0	0	0	0	0	5	11	25	121
July 10	4	1	0	3	4	4	6	11	36	121
July 11	2	1	0	5	2	6	10	12	100	144

TABLE 16.--Continued

Date	New		Mi		Wi		Xi		X^2i	
	M	F	M	F	M	F	M	F	M	F
July 12	0	0	2	2	2	2	12	13	144	169
July 13	0	1	3	1	3	2	12	13	144	169
July 17	0	4	3	3	3	7	12	14	144	196
July 18	0	2	1	2	1	4	12	18	144	324
July 20	0	1	2	2	2	3	12	20	144	400
July 24	1	0	1	1	2	1	12	21	144	441
July 25	1	2	6	3	7	5	13	21	169	441
July 26	0	0	3	1	3	1	14	23	196	529
July 27	0	0	0	1	0	1	14	23	196	529
July 28	0	0	0	1	0	1	14	23	196	529
July 31	1	0	1	1	2	1	14	23	196	529
August 1	2	0	0	1	2	1	15	23	225	529
August 2	0	0	0	1	0	1	17	23	289	529
August 8	0	0	1	0	1	0	17	23	289	529
August 13	0	1	0	0	0	1	17	23	289	529
August 27	0	1	0	1	0	2	17	24	289	576
September 12	0	2	2	1	2	3	17	25	289	625
September 13	1	0	0	2	1	2	17	27	289	729
September 14	0	0	2	0	2	0	18	27	324	729
September 15	0	1	0	2	0	3	18	27	324	729

TABLE 16.--Continued

Date	New M	New F	Mi M	Mi F	Wi M	Wi F	Xi M	Xi F	X^2i M	X^2i F
	Kinosternon subrubrum hippocrepis, 1958									
June 15	4	5	0	0	4	5	0	0	0	0
June 16	0	2	0	0	0	2	4	5	16	25
June 17	0	2	0	1	0	3	4	7	16	49
June 18	2	2	0	1	2	3	4	9	16	81
June 19	0	2	1	2	1	4	6	11	36	121
June 20	0	6	0	2	0	8	6	13	36	169
June 22	0	0	0	1	0	1	6	19	36	361
June 23	0	1	0	0	0	1	6	19	36	361
June 24	0	1	0	0	0	1	6	20	36	400
June 25	1	1	0	0	1	1	6	21	36	441
July 6	3	3	0	0	3	3	7	22	49	484
July 7	0	0	2	3	2	3	10	25	100	625
July 9	0	0	1	2	1	2	10	25	100	625
July 10	1	2	0	1	1	3	10	25	100	625
July 11	1	0	2	3	3	3	11	27	121	729
July 12	1	0	2	0	3	0	12	27	144	729
July 13	0	0	1	1	1	1	13	27	169	729
July 15	1	1	0	1	1	2	13	27	169	729
July 16	0	2	1	0	1	2	14	28	196	784
July 17	0	1	1	0	1	1	14	30	196	900
July 18	1	0	0	0	1	0	14	31	196	961
July 19	0	0	0	1	0	1	15	31	225	961
July 20	1	0	0	0	1	0	15	31	225	961

TABLE 16.--Continued

Date	New		Mi		Wi		Xi		X^2_i	
	M	F	M	F	M	F	M	F	M	F
July 25	0	2	1	0	1	2	16	31	256	961
July 27	0	0	0	2	0	2	16	33	256	1089
July 28	0	1	0	0	0	1	16	33	256	1089
September 8	0	3	2	2	2	5	16	34	256	1156
September 9	0	1	3	1	3	2	16	37	256	1369
September 10	0	0	2	0	2	0	16	38	256	1444
September 12	0	2	2	1	2	3	16	40	256	1600
September 13	1	0	0	2	1	2	16	40	256	1600

TABLE 16.--Continued

Kinosternon flavescens flavescens, 1959

Date	New			Mi			Wi			Xi			$X^2 i$		
	M	F	J	M	F	J	M	F	J	M	F	J	M	F	J
May 6	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0
May 7	0	0	2	0	0	0	0	0	2	0	0	1	0	0	1
May 8	0	0	1	0	0	0	0	0	1	0	0	3	0	0	9
May 9	0	4	0	0	0	1	0	4	1	1	0	4	1	0	16
May 10	0	0	0	0	0	0	0	0	0	0	0	4	0	0	16
May 11	0	1	0	0	0	0	0	1	0	1	4	4	1	16	16
May 18	0	3	0	0	1	0	0	4	0	1	5	4	1	25	16
May 19	0	1	0	0	1	0	0	2	0	1	8	4	1	64	16
May 23	1	2	1	0	0	2	1	2	3	1	9	4	1	81	16
May 24	2	0	0	0	1	4	2	1	4	2	11	5	4	121	25
May 25	0	0	0	0	0	2	0	0	2	0	0	5	0	0	25
June 7	2	4	0	0	0	0	2	4	0	4	11	0	16	121	0
June 30	1	0	0	2	1	0	3	1	0	6	15	0	36	225	0

TABLE 16.--Continued

	Sternothaerus odoratus, 1958									
Date	New		Mi		Wi		Xi		$X^2{}_i$	
	M	F	M	F	M	F	M	F	M	F
January 4	4	4	0	0	4	4	0	0	0	0
February 2	4	2	0	1	4	3	4	4	16	16
February 9	2	2	0	0	2	2	8	6	64	36
February 18	0	6	0	0	0	6	10	8	100	64
February 20	3	3	0	0	3	3	10	14	100	196
February 22	7	6	0	0	7	6	13	17	169	289
February 25	5	0	0	1	5	1	20	23	400	529
March 1	3	5	0	0	3	5	25	23	625	529
March 2	1	1	0	0	1	1	28	28	784	784
March 4	0	0	0	0	0	0	29	29	841	841
March 11	1	2	0	0	1	2	29	29	841	841
March 16	2	2	0	0	2	2	30	31	900	961
March 18	1	3	0	0	1	3	32	33	1024	1089
March 22	1	0	0	0	1	0	33	36	1089	1296
March 23	0	0	1	0	1	0	34	36	1156	1296
March 29	1	0	1	0	2	0	34	36	1156	1296
May 11	4	2	0	0	4	2	35	36	1225	1296
May 20	0	0	0	1	0	1	39	38	1521	1444

TABLE 16.--Continued

Date	New M	New F	Mi M	Mi F	Wi M	Wi F	Xi M	Xi F	X^2i M	X^2i F
June 28	1	1	1	0	2	1	39	38	1521	1444
June 29	3	3	0	0	3	3	40	39	1600	1521
June 30	1	0	0	0	1	0	43	42	1849	1764
July 1	0	1	0	0	0	1	44	42	1936	1764
July 2	0	1	0	0	0	1	44	43	1936	1849
July 3	1	0	0	0	1	0	44	44	1936	1936
July 8	0	4	0	0	0	4	45	44	2025	1936
July 16	1	0	0	0	1	0	45	48	2025	2304
August 7	1	0	0	0	1	0	46	48	2116	2304
August 25	0	1	0	0	0	1	47	48	2209	2304
August 26	2	5	1	0	3	5	47	49	2209	2401
August 27	8	4	0	0	8	4	49	54	2401	2916
August 28	4	3	1	1	5	4	57	58	3249	3364
August 29	6	9	1	0	7	9	61	61	3721	3721
September 9	1	0	0	0	1	0	67	70	4489	4900
September 10	0	0	1	0	1	0	68	70	4624	4900
October 2	10	1	1	1	11	1	68	70	4624	4900
October 9	1	0	0	0	1	0	78	71	6084	5041
October 10	1	3	1	1	2	4	79	71	6241	5041
October 11	4	6	4	3	8	9	80	74	6400	5476

TABLE 16.--Continued

Date	New		Mi		Wi		Xi		X^2i	
	M	F	M	F	M	F	M	F	M	F
October 12	0	1	0	0	0	1	84	80	7056	6400
October 18	0	3	0	0	0	3	84	81	7056	6561
October 19	2	3	1	2	3	5	84	84	7056	7056
October 20	0	0	1	1	1	1	86	87	7396	7569
November 2	0	0	0	1	0	1	86	87	7396	7569
Sternothaerus odoratus, 1959										
February 18	1	1	0	0	1	1	0	0	0	0
March 19	7	3	0	0	7	3	1	1	1	1
June 10	0	2	0	0	0	2	8	4	64	16
June 11	5	1	0	0	5	1	8	6	64	36
June 12	4	4	0	1	4	5	13	7	169	49
June 13	0	3	0	2	0	5	17	11	289	121
June 14	1	1	2	1	3	2	17	14	289	196
June 15	3	0	0	0	3	0	18	15	324	225
June 16	2	0	1	3	3	3	21	15	441	225
June 17	2	1	1	0	3	1	23	15	529	225
August 6	5	10	1	1	6	11	25	16	625	256
August 7	4	1	1	1	5	2	30	26	900	676

TABLE 16.--Continued

Date	New		Mi		Wi		Xi		X^2i	
	M	F	M	F	M	F	M	F	M	F
September 8	0	1	0	1	0	2	34	27	1156	729
September 9	3	1	0	0	3	1	34	28	1156	784
September 10	1	1	2	2	3	3	37	29	1369	841
November 1	3	0	0	2	3	2	38	30	1444	900
December 6	0	0	0	1	0	1	41	30	1681	900

TABLE 16.--Continued

Date	New			Mi			Wi			Xi			X^2i		
	M	F	J	M	F	J	M	F	J	M	F	J	M	F	J
Sternothaerus carinatus carinatus, 1958															
May 24	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0
May 25	0	0	1	0	0	0	0	0	1	0	0	4	0	0	16
July 9	0	0	0	0	0	1	0	0	1	0	0	5	0	0	25
August 9	0	1	0	0	0	0	0	1	0	0	0	5	0	0	25
August 23	1	0	0	0	0	0	1	0	0	0	1	5	0	1	25
September 2	2	5	2	0	0	0	2	5	2	1	1	5	1	1	25
September 3	0	3	0	0	0	0	0	3	0	3	6	7	9	36	49
September 4	4	3	1	0	0	0	4	3	1	3	9	7	9	81	49
September 5	1	3	2	0	0	0	1	3	2	7	11	8	49	121	64
September 6	1	2	0	0	0	0	1	2	0	8	14	10	64	196	100
September 7	2	1	0	0	0	0	2	1	0	9	16	10	81	256	100
Sternothaerus carinatus carinatus, 1959															
July 7	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0
July 10	3	1	2	0	0	0	3	1	2	0	0	2	0	0	4
July 11	4	1	0	0	0	0	4	1	0	3	1	4	9	1	16
July 12	0	1	1	1	1	0	1	2	1	7	2	4	49	4	16
July 13	1	0	8	0	0	0	1	0	8	7	3	5	49	6	25
July 14	2	4	5	0	0	0	2	4	5	8	3	13	64	9	169

TABLE 17.--Population estimates for the four kinosternid turtles in Oklahoma, 1956-1959

Species	Hayne's Method	Lincoln Index Method	Turtles per Acre Based on Lincoln Index Method
Kinosternon subrubrum hippocrepis (Cowan Creek)	1956: 40 female, 54 male	1956: 47 female, 33 male	64.5369
	1957: 27 female, 18 male	1957: 60 female, 70 male	104.6725
	1958: 58 female, 20 male		
Kinosternon flavescens flavescens (Berry's Pond)	1959: 32 female, 10 male, 5 juvenile	1958: 57 female, 36 male, 12 juvenile	11.3749
Sternothaerus odoratus (Honey Creek)	1958: 361 female, 275 male	1958: 167 female, 221 male	60.7959
	1959: 53 female, 125 male		
Sternothaerus carinatus carinatus (Mountain Fork River)	1958: 54 female	1958: 144 female, 121 male, 198 juvenile	92.6000
	1959: 11 female, 37 male		

CHAPTER X

COURTSHIP

Courtship in the four species was frequently observed in captivity and only occasionally in the field; 13 and 5 for *K. s. hippocrepis*, 78 and 3 for *K. f. flavescens*, 31 and 5 for *S. odoratus* and 7 and 3 for *S. c. carinatus* respectively.

Courtship activity in the field appeared sporadically in *K. f. flavescens* from April through July and from April through September in the other three species. In captivity they showed the same pattern except for *K. f. flavescens* which performed courtship activity sporadically throughout the year.

Courtship performances of captive individuals were observed in a concrete tank measuring two feet by six feet long, with a depth of five inches. Water temperatures at which courtship was observed ranged between 20°C and 30°C.

In the male of these species of turtles, the tail is much longer and thicker than that of the female, and two scaly-patches are present on the posterior surfaces of his hind legs. These dimorphic features served as grasping organs during mating.

With the exception of some minute differences, the courtship performances in the four species were very similar and were divided into three phases: the tactile phase, the mounting phase, and the biting and rubbing phase.

During the tactile phase, the male, with his neck extending forward, approached another turtle from behind, and with his nose, felt or smelled the tail of the other turtle apparently to determine its sex. Courtship usually proceeded no further if the approached turtle was a male. If the courted turtle was a female, the male, with his neck still extending forward, moved to the right or the left side of the female, "nudging" the area around her bridge with his nose. If the female was not receptive, she moved away from the male, to which the male responded by either giving chase or moving away.

If a chasing response occurred, the chasing male, his neck fully extended, then attempted persistently to nudge her about the head as he followed her. The chase was sometimes followed by mounting a few seconds later.

If the female was receptive, she remained still as the male, with his neck fully extended, gently nudged her just posterior to the eye, and a few seconds later assumed the mounting position. This tactile phase varied from a few seconds to three minutes.

The mounting phase usually followed the tactile phase, though the mounting phase was apparently performed directly in a number of observations.

Males were observed to approach to mount the females from either the posterior or from the right or left side of her carapace. Lagler (1941) also observed the two approaches in S. odoratus preceding mounting. From either of the above approaches, the male quickly assumed a position with his plastron directly over the female's carapace, immediately grasping the margins of her carapace with the toes and claws of his four feet. The pair then sank to the bottom of the tank. During the mounting the following actions occurred simultaneously: (1) The male, by flexing one (either right or left) knee, held the female's tail between the two scaly patches on the opposing posterior surfaces of the upper and lower leg. (2) The male's tail looped with its terminal nail touching the area proximal to one or the other side of the female's cloaca, bringing the cloacas together. (3) The male's head extended forward gently to touch the top of the female's head and neck. Then the male's penis was inserted into the female's cloaca. When this coital position was gained, the rubbing and biting phase started. The time between the male mounting the carapace and penal insertion varied from five to ten seconds.

Since the males of the four species reached sexual maturity at a smaller size than the females, some variation in the male's position was observed during mounting. If a male mounted a larger female, he took a position more toward the posterior portion of her carapace with his head and neck fully extended forward touching the anterior midline edge of her carapace. However, if the male was equal in size or larger than the courted female, then his plastron was directly over her carapace. Even in S. c. carinatus the sharply keeled back of the female was directly under the midline of the male's plastron.

After the pair gained the coital position, the male, with his neck fully extended and his head bent downward, rubbed the top of the female's head and neck with his chin, occasionally biting the back of her neck or head, frequently forcing approximately half of her neck to retract inside her shell. The female sometimes retaliated by biting the male about his head or his front feet and at the same time tilting her body from one side to the other continuously.

In *K. f. flavescens* a pair of turtles may stay in coital position for a period varying between ten minutes and three hours, while in the other three species, this period varied from five minutes to two hours.

Courtship in nature usually took place in water varying in depth from one inch to several feet. On one occasion, however, a pair of *K. f. flavescens* was seen in the mounted position on the edge of a pond. The complete courtship performance was never observed in nature, though pairs were often seen in coital position.

When males of *K. f. flavescens* were kept together in a concrete tank, mounting between two males was very common but usually lasted only a few minutes. The smelling phase was missing from such performances. Whether this courtship between two males was due to poor sex recognition or homosexuality remained unknown, and it was not observed for the other species. Occasionally a male *K. f. flavescens* courted a male or female *K. s. hippocrepis*. Taylor (1933) observed a male *K. f. flavescens* attempting to copulate with small female *Chrysemys*. The lack of interspecific courtship in

S. odoratus, *S. c. carinatus*, and *K. s. hippocrepis* may be due to more adequate sex recognition in these forms.

The relatively small size of *S. odoratus* and the sharply keeled carapace of *S. c. carinatus* may be important in species recognition.

CHAPTER XI

REPRODUCTION

Compared with the other aquatic species of turtles in North America, the number of eggs per clutch was very small in the turtles studied. Of 18 *K. s. hippocrepis*, 17 *K. f. flavescens*, 10 *S. odoratus*, and 7 *S. c. carinatus* examined, the size of the clutch ranged between 2 and 5 (mean 3) in *S. odoratus*; 4 and 6 (mean 5) in each of the other three species. The egg laying season (from the oviducal dissection of the four species) probably extended from May to October in *S. odoratus*; June to July in *K. f. flavescens*; June to October in *K. s. hippocrepis* and *S. c. carinatus*. Eggs were dissected from the oviducts in every month of the breeding season.

The ovaries of the females of each of the four species were at their maximum weight in early April when oviducal eggs were still absent. During the egg laying season there was a gradual decrease in the ovarian weight (fig. 49) in relation to other turtles. Cagle (1950) stated that the weight of the ovaries of female *Pseudemys scripta troosti* containing oviducal eggs showed progressive mean increase in weight during the egg laying season. In the four species studied, there was no correlation between the ovarian weight and the carapace length throughout the season.

Each of the ovaries dissected from the female turtles of the four species had several size-group ovarian follicles. These follicles ranged in size from .025 to 2.00 cm.

In the mature female turtles of the four species, the number of ovarian follicles of each size-group correlated with the number of eggs of each clutch when those follicles reached the size of 0.5 cm in diameter. The size-group of the ovarian follicles varied between .025 and 2.00 cm in diameter and there were 5 to 8 different size groups in each mature ovary. The total number of follicles in each ovary varied between 120 and 150.

From the ovarian follicles, it was possible to estimate the future reproductive potential of the turtles for the next two years. The turtles with ovarian follicles slightly greater than 1.00 cm were probably capable of laying eggs during the next reproductive season; while the turtles with ovarian follicles slightly less than 0.5 cm were probably capable of laying eggs for the next two years. The above idea concerning the future reproductive potential of turtles was suggested by Cagle (1944) while he was working on the turtle *Pseudemys scripta elegans*.

The long egg laying season in *S. odoratus*, *S. c. carinatus* and *K. s. hippocrepis* suggests that the females of these forms may deposit two or three clutches of eggs per season. The equal size of the ovarian follicle to that of the yolk of the egg in those females containing oviducal eggs during early May suggests that the turtles might lay two or three clutches of eggs in one season. Mitsukuri (1895) observed that the Japanese soft shelled turtle (*Trionyx japonicus*) was able to deposit four clutches of eggs per season. Deraniyagala (1939) observed that soft terrapin (*Lissemys punctata granosa*) and the starred tortoise (*Testudo elegans*) laid several clutches of eggs within a few weeks. Hildebrand (1932), Moorhouse (1933), and Cagle (1950) stated that the turtles may lay more than one clutch of eggs per season. Three female *K. s. hippocrepis* which were dissected during July had follicular scars in the ovaries exceeding the number of the oviducal eggs found, which suggested that these turtles may have deposited one clutch of eggs prior to their capture.

In nature, the exact period of incubation for the eggs of the four species is unknown. However, recently hatched turtles were observed in late summer, late fall and early spring. This suggested that the period of incubation ranged from 80 to 90 days for those eggs laid during June or July. However, for those eggs laid during the fall, the hatchlings probably spent the winter in their nest and emerged the following spring. Hartweg (1944) observed that the hatchlings of the painted turtle (*Chrysemys picta marginata*) in Michigan spent the winter in their nest and emerged the following spring. Five eggs were taken from a female *K. f. flavescens* on July 1, 1959; the eggs were placed in a small screen container and covered by three inches of sand. At a temperature varying between 75°C and 85°C, the eggs hatched 94 days later. However, when five oviducal eggs of *K. s. hippocrepis* were incubated in the laboratory on August 5, 1959 (using the above incubation method and almost the same room temperature) these eggs hatched on December 23, 1959 (140 days later). Undoubtedly these hatchlings would have spent the winter in their nest if the hatching occurred in nature.

The size of the eggs in each of the four forms was variable. A total of 54, 68, 23 and 20 eggs of K. s. hippocrepis, K. f. flavescens, S. odoratus and S. c. carinatus respectively were dissected from the oviducts. The means and ranges for the lengths, width, and weights of these eggs are:

	Mean length in cm	Mean width in cm	Mean weight in grams
K. s. hippocrepis	2.70 (2.31-3.00)	1.63 (1.39-1.69)	4.20-3.37 (3.53)
K. f. flavescens	2.75 (2.30-3.10)	1.75 (1.45-1.75)	4.23-3.41 (3.54)
S. odoratus	2.63 (2.15-3.02)	1.55 (1.36-1.68)	3.88-3.22 (3.41)
S. c. carinatus	2.70 (2.40-3.10)	1.78 (1.44-1.80)	4.31-3.44 (3.55)

The shape of the eggs of the four species was generally ovoid but slight variation in the shape was noticed. The egg shell was hard and white. In the four species there was no correlation between spermatogenesis and ovulation. Spermatogenesis started some time during May with a gradual increase in the weight of testis until they reached their maximum weight some time between July and August (fig. 50). Risley (1938) observed the same on S. odoratus in Michigan.

The accumulation of sperm was greater in the epididymis during the winter and spring but more sperm were in the testis during late summer and fall.

In the four species there was no significant size and weight difference in the left and right testis.

Figure 49

Relationship between the carapace length and the weight of right or left ovary in the four species of kinosternid turtles of Oklahoma, 1956-1960. Dots = weight of ovary from April to October; circles = weight of ovary from December to March.

Figure 50

Relationship between the carapace length and the weight of right or left testis in the four species of kinosternid turtles of Oklahoma, 1956-1960. Dots = weight of testis from October to May; circles = weight of testis from May to September.

CHAPTER XII

MORTALITY AND PREDATION

Most herpetologists believe that man is the greatest enemy of turtles. Cagle (1950) says:

> Man is possibly the greatest enemy of the slider turtle in all parts of the range. Fishermen destroy the turtles at every opportunity in the mistaken belief that they are harmful to fish populations. In the South the juveniles are collected by the thousands for sale as pets and the eggs are sometimes harvested for fish bait. The great demand for small turtles in the novelty trade has led many professional collectors to collect eggs and incubate them to procure the turtles.

The turtles of the four forms were easily attracted by bait and fishermen probably catch them by the thousands every year. On several occasions recently killed turtles with their heads cut off were found near bodies of water. On August 15, 1959, two fishermen caught and killed 51 adult *S. c. carinatus* in two hours from the Blue River near Milburn, Oklahoma.

Some fish and water snakes (*Natrix*) are probably common predators on the hatchlings of the four species. On

April 3, 1959, Mr. Richard Diener forced a *Natrix rhombifera* to regurgitate a small *K. s. hippocrepis* (carapace length 3.92 cm). On two occasions, gar (*Lepisosteus*) were observed to capture small *K. s. hippocrepis* in Lake Texoma. Raccoons and skunks have been reported to be great predators on turtles' eggs in general and these predators probably account for the destruction of many of the eggs and nests of the four species studied.

Mortality during hibernation is not likely to occur very frequently in Oklahoma since these turtles can tolerate very low temperature. Drought, however, might cause high mortality. During 1955 and 1956, drought was thought to have killed several *K. f. flavescens* in the Oliver Wildlife Preserve.

CHAPTER XIII

DISCUSSION

Each species of animal has specific ecological requirements which tend to limit that animal to a specific habitat niche. The ecological requirements of each form are directly related to its behavior, physiology and morphology.

The four species concerned were europhagic and omnivorous, and their food selection was related to the availability of food. The food habits were not considered to be a limiting factor in the ecological and geographical distribution of the Oklahoma kinosternid turtles.

The thermo-activity range differed only a few degrees among the four species and they showed little behavioral thermoregulation. Temperature, also, was thought to have little or no effect in determining the ecological and geographical distribution in any of the four species.

Habitat preference was the most likely factor determining the ecological and geographical distinctions of the four species.

A xeric habitat with temporary bodies of water located on the grasslands was preferred by *K. f. flavescens*. Their tendency to aestivate in late summer was an adaptation to the transient nature of these water bodies. The food of this species consists largely of animals such as tadpoles, molluscs, aquatic insects, and crustaceans which were abundant during the spring to early summer in temporary waters and gradually decreased in the later part of August. The seasonal activity of *K. f. flavescens* was thus closely associated with the habitat conditions and food availability.

K. f. flavescens was the least aquatic and the most migratory of the four. Migration is a beneficial adaptation to xeric habitats. Although permanent lotic habitats were found throughout the range of this species, this turtle was very rarely taken from such habitats. Cahn (1937) stated that over many years of investigations on the Illinois River, no *K. f. flavescens* were recorded. The only body of water approaching permanency that this species occupied was the man-made farm pond.

On the other hand, permanent bodies of water in wooded areas were the preferred habitats of *S. odoratus*, *S. c. carinatus* and most of the *K. s. hippocrepis*. These species are strictly aquatic. Terrestrial migrations occurred only during the breeding season. Although temporary bodies of water occurred throughout the range of S. odoratus and S. c. carinatus, these species were not found in them, and K. s. hippocrepis very seldom occupied them. Aestivation appeared lacking in these species, probably due to the presence of mesic habitats with permanent bodies of water found throughout their range.

During its short period of seasonal activity, K. f. flavescens was active every day. The swimming ability and maneuverability of K. f. flavescens exceeded that of the other species which were slower swimmers and showed less maneuverability. This greater agility and continuous activity on the part of K. f. flavescens increased its efficiency in obtaining food and were probably adaptations to the short annual activity and feeding period.

Water turbidity was a limiting factor for S. odoratus and S. c. carinatus. They were never taken from traps set in highly turbid waters. K. f. flavescens and K. s. hippocrepis were trapped from waters of all degrees of turbidity. Laboratory observations indicated that K. f. flavescens and K. s. hippocrepis had a better sense of vision than S. odoratus and S. c. carinatus, and the former were, therefore, better adapted to a turbid water habitat.

Water depth and bottom type were also ecological factors separating _K. f. flavescens_ and _K. s. hippocrepis_ from _S. c. carinatus_ and _S. odoratus_.

The shape and size of the activity range were perhaps influenced to a great extent by habitat conditions. Since frequent migration over land was characteristic of _K. f. flavescens_, it was assumed that this contributed to their larger activity ranges. The wandering movement was probably due to forced migration away from unsuitable habitat conditions caused by drought and food shortage. Migration over land was rare or lacking in the other three species and probably was due to the greater stability of their preferred habitats and their marked aquatic tendencies. The turtles of the four forms maintained similar limited activity ranges, which implied space consciousness and homing ability.

Bogert (1949) stated that "lizards belonging to the same genus tend to have similar, but not necessarily identical, mean body temperature preferences, even if they live in different habitats and climatic regions." The two genera studied had similar mean body temperatures. Perhaps it is safe to conclude that the two genera show taxonomic affinities in this respect.

Tinkle (1958) proposed _S. odoratus_ as the most primitive living species in this genus and also proposed that the _S. carinatus_ complex (with the exception of _S. minor minor_) differentiated from either _S. odoratus_ or a common stock derived from _S. odoratus_.

S. odoratus, in the light of the present work, had the widest thermo-activity range of the four species and probably has the widest thermo-activity range of the kinosternid turtles in North America. It is the most northern and widely distributed kinosternid species in North America. Tinkle (1958) stated that "_Sternothaerus odoratus_ may have achieved its present distribution since the Pleistocene or it may have survived farther north during this period than members of the _Sternothaerus carinatus_ group." It is likely that _S. odoratus_ resisted the cold climate of the Pleistocene (since it has a wide thermo-activity range) and thus has maintained its northern distribution.

CHAPTER XIV

SUMMARY AND CONCLUSIONS

A total of 1,200 field records was obtained for 911 individuals of the four species of kinosternid turtles known for Oklahoma: (*Kinosternon subrubrum hippocrepis*), (*Kinosternon flavescens flavescens*), (*Sternothaerus odoratus*), (*Sternothaerus carinatus carinatus*).

Information relative to habitat preference, temperature, diel cycle, seasonal periodicity, feeding habits, movements, growth, reproductive potential, behavior, and population was gathered from seven marked natural populations, from random collections over the state, and from observations on laboratory populations.

The four species showed little or no behavioral thermo-regulation. The thermo-activity range was broader in *Sternothaerus* than in *Kinosternon*.

The rhythmic pattern of the diel cycle was influenced by temperature and light intensity.

The annual activity periods for _Sternothaerus odoratus_ and _Sternothaerus carinatus carinatus_ were estimated to be 330 and 331 days respectively, in contrast to 265 days for _Kinosternon subrubrum hippocrepis_ and 140 days for _Kinosternon flavescens flavescens_.

The breeding season for _Sternothaerus odoratus_, _Sternothaerus carinatus carinatus_, and _Kinosternon subrubrum hippocrepis_ extended from April to October, and for _Kinosternon flavescens flavescens_ the breeding season was from April to July. Eggs were found in the uteri of these species throughout this period. The size of egg clutch varied between 3 and 6. The courtship performance was similar in the four species and involved nudging, smelling, mounting, and biting and rubbing.

Adult females outnumbered adult males and adults were more numerous than hatchlings at all times of the year. Population estimates for the four species were: 60.79 per acre for _Sternothaerus odoratus_, 92.60 per acre for _Sternothaerus carinatus carinatus_, 104.67 per acre for _Kinosternon subrubrum hippocrepis_, and 11.37 per acre for _Kinosternon flavescens flavescens_.

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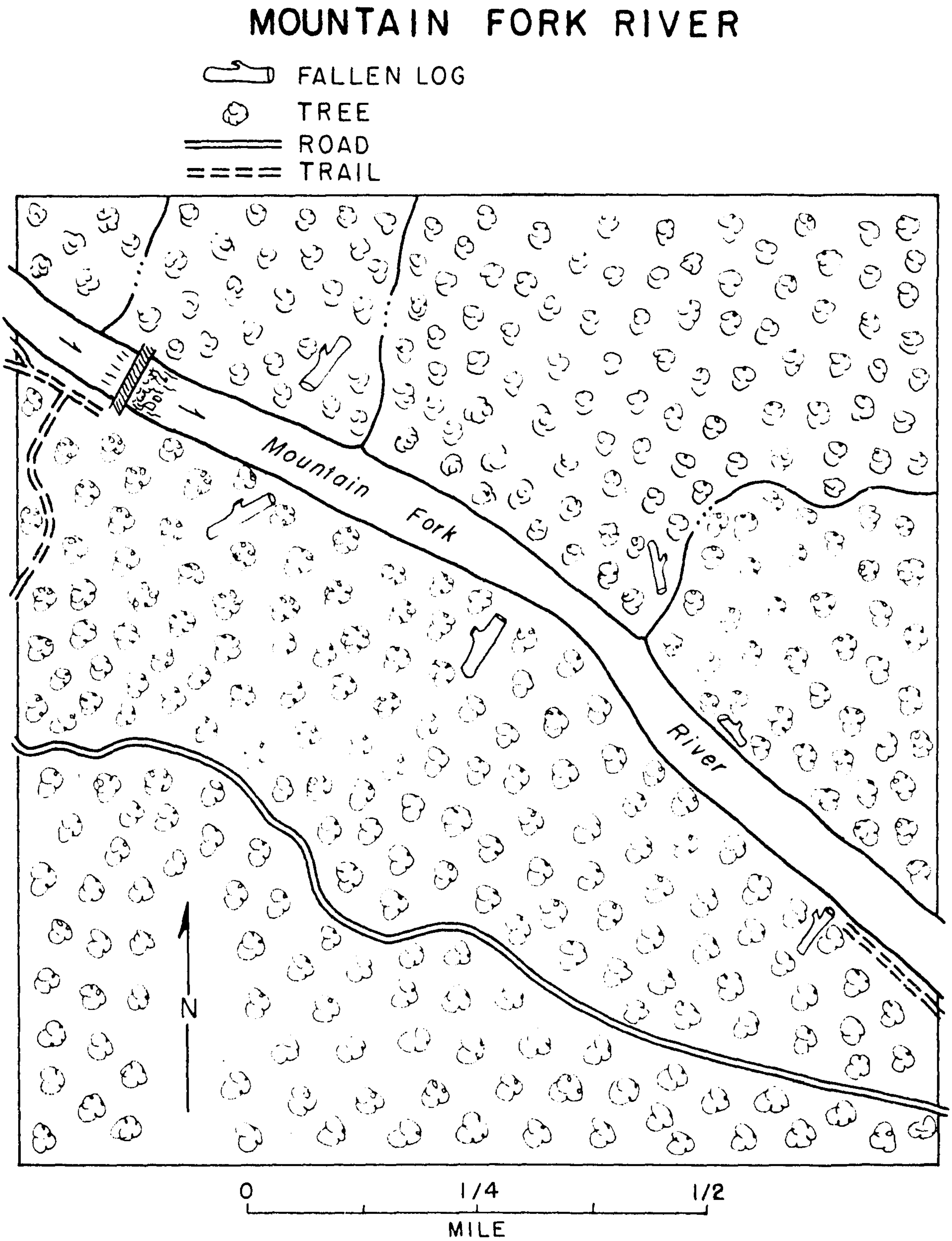
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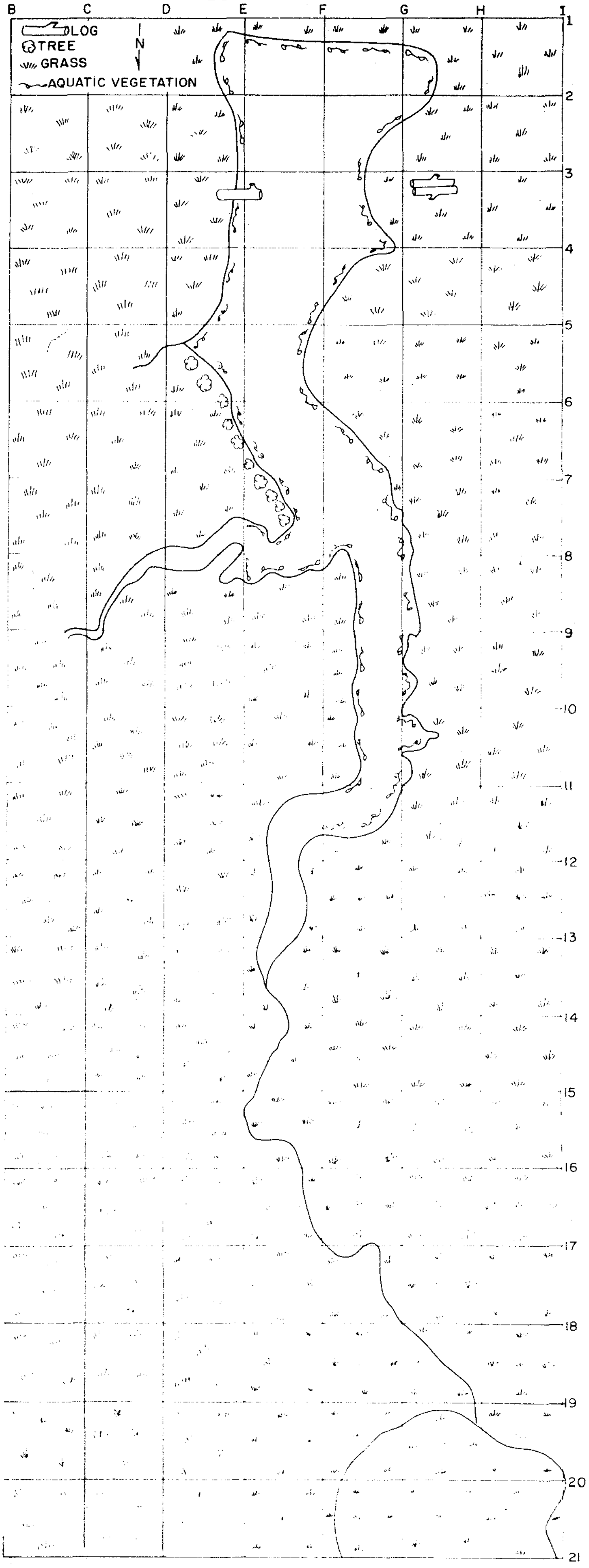
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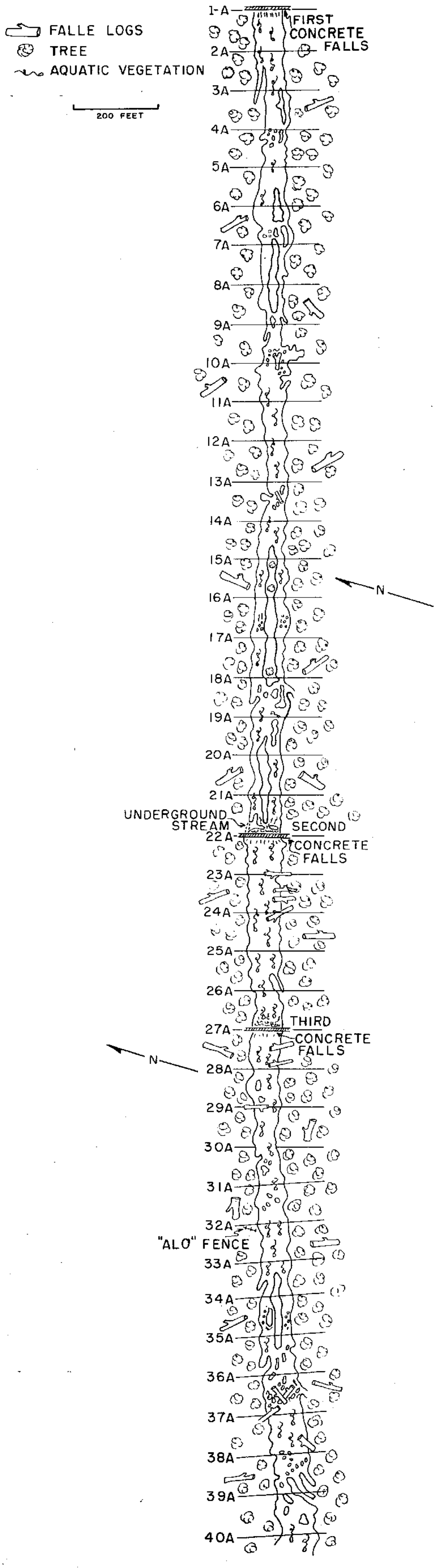
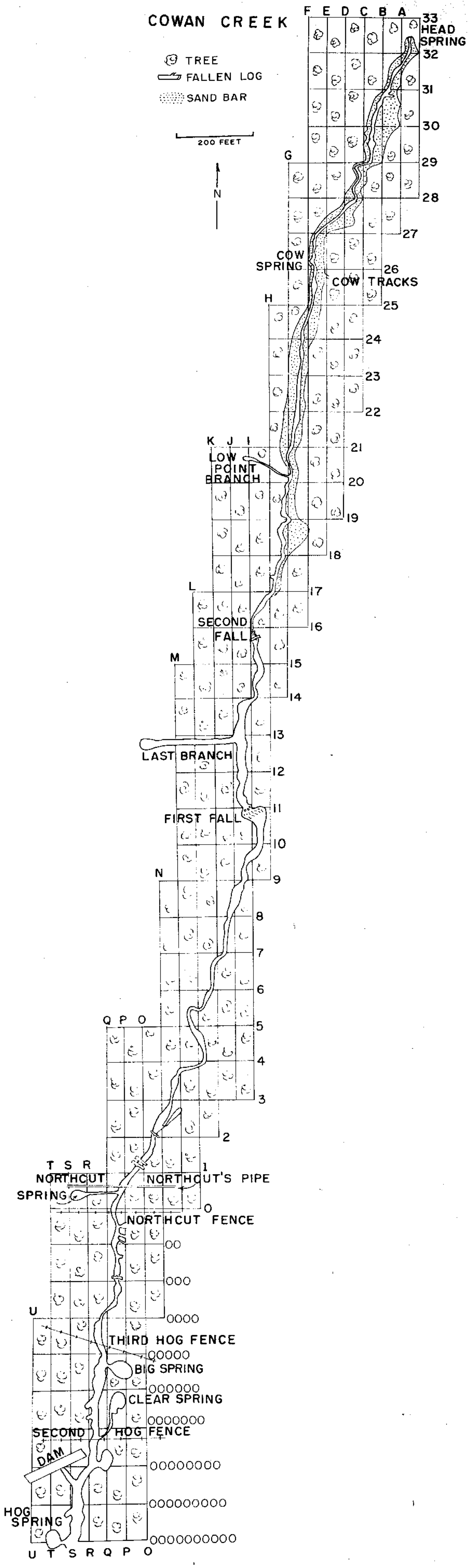
19
20
21

HONEY CREEK


FALLE LOGS
TREE
AQUATIC VEGETATION
200 FEET
1-A
FIRST CONCRETE FALLS
2A
3A
4A
5A
6A
7A
8A
9A
10A
11A
12A
13A
14A
15A
N
16A
17A
18A
19A
20A
21A
UNDERGROUND STREAM
22A
SECOND CONCRETE FALLS
23A
24A
25A
26A
27A
THIRD CONCRETE FALLS
N
28A
29A
30A
31A
32A
"ALO" FENCE
33A
34A
35A
36A
37A
38A
39A
40A



COWAN CREEK
TREE
FALLEN LOG
SAND BAR
200 FEET
N
F E D C B A
33
HEAD SPRING
32
31
30
G
29
28
27
COW SPRING
26
COW TRACKS
25
H
24
23
22
K J I
21
LOW POINT BRANCH
20
19
18
L
17
SECOND FALL
16
M
15
14
13
LAST BRANCH
12
11
FIRST FALL
10
N
9
8
7
6
Q P O
5
4
3
2
T S R
1
NORTHCUT SPRING
NORTHCUT'S PIPE
0
NORTHCUT FENCE
00
000
U
0000
THIRD HOG FENCE
00000
BIG SPRING
000000
CLEAR SPRING
0000000
SECOND HOG FENCE
DAM
00000000
HOG SPRING
000000000
0000000000
U T S R Q P O