HABITAT, HOME RANGE AND POPULATION STUDY OF THE EASTERN BOX TURTLE (*TERRAPENE CAROLINA*)

by

Lynette Hallgren-Scaffidi

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Name of Candidate: Lynette Hallgren-Scaffidi
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Thesis and Abstract Approved: Vagn Flyger
Dr. Vagn Flyger
Professor
Animal Science

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ABSTRACT

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Lynette Hallgren-Scaffidi, Masters of Science, 1986

Thesis directed by: Dr. Vagn Flyger
Professor
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This study covers the home range, population size, habitat type and components of habitat of the eastern box turtle, Terrapene carolina. The study area was within the floodplains of the Patuxent River on the grounds of Patuxent Wildlife Research Center, Laurel, Maryland. A home range and population study was conducted by Lucille Stickel in 1945 within the same study-area and provided a basis for comparative analysis including information on population trends.

Mark-recapture data and a tread-trailer device were used to estimate populations, trace the daily route of eleven individual turtles, and home range size. The range length and convex polygon methods were used to calculate home range size. The average box turtles home range as calculated by the range length method was .733 hectares. In addition the average area calculated by the convex polygon method is .955 hectares for the thread-trailer technique. These home range estimates depict a small reduction in range size from Stickels original estimates Forest maturation is proposed as one of the primary factors influencing this reduction of range size.

The population size of the box turtle within the study-area was ascertained by mark-recapture techniques. Using the Schnabel Method of estimating population size, an average of 8.62 (8.30 for 1984; 8.92 for

1985) turtles per hectare was determined. The total number of turtles found during the 1985 study season (58) in comparison to the total number found during the 1945 study season (284) demonstrates the declining population of the Patuxent box turtles over the last four decades.

The largest population of box turtles were found in forest habitats or forest-field ecotones. Determination of box turtles preference for habitat types and components of habitat was emphasized in this study. Two habitat types, 'dried streambeds' and 'woods opening', encompassed the smallest areas of the study site while providing habitat for the greatest number of turtles. In addition many turtles showed preference for two components of habitats (out in the open and under a log). However, because it is easier to locate turtles out in the open, it is proposed here that the large number of turtles found in this Component of Habitat is due to bias surveying techniques and not a preference for turtles. The results also provide information for improving box turtle habitat within parklands.

Changes to the study-area and surrounding ecosystems have occurred over the past four decades. The forest has matured, upstream waters have been impounded by dams, filtration plants built and increased pollution of the Patuxent River have occurred. The decline in box turtle abundance is probably due to the frequent floods that inundate turtle eggs when upstream dams are opened.

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INTRODUCTION

This is a report of a study on home range, population size and habitat requirements of the eastern box turtle, *Terrapene carolina*. Detailed observations of habitat types, and components of habitat at the observation point of each turtle affords a unique opportunity to determine specific preferences and requirements of the box turtle.

The study was conducted on the Patuxent River floodplain within the Patuxent Wildlife Research Center; Laurel, Maryland. A population and home range study in the same area was originally conducted by Lucille Stickel between 1944 and 1947. Because of Stickel's initial research, the Patuxent floodplain box turtle population was chosen for this study, Comparative analysis of home range and population size estimates for both studies may provide long range population trends of this long lived species as well as ecological information of its habitat and surrounding ecosystems.

BACKGROUND

Breder (1927) originated extensive studies of home range size of land turtles (Terrapene carolina) by attaching a spool of thread to the back of a turtle in order to follow and record the turtles exact travels. Breder's conclusions suggested that each box turtle occupies 'an area of circumscribed dimension; a home range'.

Cagle (1944) investigated three turtle species, Chrysemys scripta elegans (red-eared turtle), Chrysemys picta (painted turtle), and Terrapene carolina for habitation of a home range. Based upon results from mark-recapture techniques, all three species were determined to possess home ranges. However, aggressive, territorial behavior was not displayed by the turtles.

Stickel (1950) estimated population and home range size by repeated captures of marked turtles. More detailed data on range size was provided by the thread trailer device devised by Breder (1927). All turtles located four or more times (the average number of recaptures per animal was eight) were used to estimate average home range size. Thread trailers, placed on eleven turtles, provided records of individual turtle activity for periods of 1 to 44 days with the exception of one turtle which was followed for 161 days. Stickel ascertained that home ranges overlapped grossly ; thus confirming Cagle's (1944) assumption that box turtles do not defend territories.

The turtle population study was repeated each decade after 1945 using the procedures established by Stickel (1978), and provided information on population dynamics of this long-lived species in its native habitat.

Schwartz and Schwartz (1974) reported results from a nine year study of population and home range size of Terrapene carolina on a 55 acre study-site in Missouri. The Schwartzes employed repeated captures (using dogs to locate the turtles), thread trailers, and radiotelemetry to estimate range size. Miniature radio transmitters were attached to five turtles whose home ranges had been previously determined by repeated captures. Estimated home ranges using radiotelemetry were smaller than range estimates determined by repeated captures in four of the five cases (The fifth radiotelemetry estimate was 2.04 times larger than its mark-recapture counterpart). In addition, observation of surroundings of each located turtle provided information about habitat utilization by turtles. The greatest number of box turtles were found in woodland habitats and forest-field ecotones, suggesting preference for these two habitat.

Madden (1975) conducted a study of home range size and habitat preference ofTerrapene carolina in the Kalbfleish Field Research Station on Long Island. Home ranges in this study were calculated on the basis of radiotelemetry recordings of 23 turtles for periods of 50 to 480 days. Madden's observation of habitat preferences agrees with Schwartz and Schwartz (1974) in suggesting that turtles concentrate their activities in the forest-brush and forest field ecotones.

Each of the above mentioned studies provided extensive information of home range and population size of Terrapene carolina. However, information on habitat preference and requirements are yet in the primitive stages. This study investigates preference of habitat types and components of habitat based upon distribution of turtles amoung these areas.

In this present and unrelenting era of rapid reduction of natural ecosystems, man must attempt to expand his knowledge of macro and microhabitat requirements of all wildlife species to aide management of remaining parklands in improving and maximizing habitat capacity. In light of this, the discussion of this report provides guidelines for management of wildlands establish and maintain prime box turtle habitat.

The present study, in conjunction with Stickel's work, provides a long term monitor system for the Patuxent box turtle population and the ecosystem of the area. The benefits of such studies were best explained by Schwartz and Schwartz (1974):

"Because many turtles live in a relatively small area for many years, and because they are extremely long lived; this common species can be considered a significant indicator of environmental conditions of its habitat over a long period. A continuing study of this animal affords a unique opportunity for long range ecological information as contrasted to most vertebrae species which are relatively shorter lived or have larger home ranges."

Habitat preference;

The eastern box turtle has been found in all habitats, but is essentially considered a woodland species (Stickel, 1950; Allard, 1948). Stickel (1950) and Strang (1983) have contrasting opinions as to the prefered habitat of this specie. Stickel concludes the box turtles are far more numerous on floodplains. Strass, studying a population at the Florence Jones Reinemand Wildlife Sanctuary on in the Blue Mountain Pennsylvanian Appalachians, found that the box turtles were distributed equally among: lowland habitat, a mid-successional forest dominated by oaks (Quercus spp.), black birch (Betula lenta), and red maple (Acer rubrum); upland habitat consisting of rocky areas, drier soil and less diverse oak-dominated tree flora; and yellow pine knob habitat containing acidic red soil and flora dominated by oaks, pitch pine (Pinus rigida), blueberry

(*Vaccinium* spp.) thickets and mosses.

One of the most conspicuous characteristics of habitat utilization by box turtles is their extensive use of cover during inactivity (Stickel, 1950). Tangles of vines and briars, heaps of debris formed during scouring floods and brush piles are all common features of floodplains. These areas provide ample hiding places for box turtles during their periods of inactivity. Networks of natural drainage channels, or dried streambeds, lacing bottomlands offer favorable basking areas readily used by box turtles (Stickel, 1950). During the hotter periods of the year, box turtles prefer damp habitats and shade. Swampy areas and thick canopy are frequently encountered features in floodplains as opposed to the drier upland and yellow pine knob habitats noted previously (Allard, 1948).

A second type of habitat utlilization is the use of "forms". A form is a cavity excavated by the box turtle in a superficial layer of leaves, debris, low dense vegetation, or soil (Stickel, 1950; Strass et al, 1982). Box turtles probably create forms for a number of reasons: for prevention of desication during dry periods; for concealment from predators during inactivity; for retreat during hot periods, and for avoiding periods of high mosquito activity (Allard, 1935; Crans and Rockel, 1968; Strass et al, 1982). In dry or unusually hot or cold weather, a turtle may remain in a form for extended periods of time. During fall, forms are excavated to progressively greater depths as cooler weather approaches (Stickel, 1950).

Dietary preference;

The box turtle is an omnivorous feeder, eating almost anything it find. Mushrooms, insects and their larval stages, earthworms, slugs, snails, carrion, blackberries, strawberries, and other fruits provide most of the dietary needs of the turtle (Allard, 1935; Stickel, 1950; Dickson, 1953). The primary food of box turtles diet varies with seasons and habitats (Stickel, 1950). When fungi, fruits and flowers are relatively scarce, box turtles feast mainly on invertebrates (Strang, 1983). Beetles, spiders, millipeds, harvestman, snails and mushroons are all commonly found in bottomlands, such as the Patuxent study-area (Stickel, 1950).

Reproduction;

Females often travel long distances at egg laying time, between June and mid-July. At such times they may leave their normal home ranges in search of suitable site to deposit their eggs. The length of egg-laying trips is believed depended on the distance between home ranges and suitable nesting sites. Minimal distances were estimated by captures of female turtles outside their estimated home range during the egg-laying period. Distances ranging between 750 meters to 774 meters have been noted (Stickel, 1950).

Egg-beds are excavated each spring by females using their powerful hind feet. A flask-shaped cavity is created with an average depth of two to three inches below the soil surface (Allard, 1948; Dickinson 1953). An average of four eggs (range two to seven) are deposited in each egg-bed then covered with soil (Allard, 1948).

The incubation period is governed to a large degree by soil temperature with higher temperatures accelerating embryonic growth (Allard, 1935). Normal incubation periods for the Washington, D.C. area have been established as approximately three months (Allard, 1948). Turtle eggs are covered by a leathery shell which provides a permeable layer between the embryo and its surrounding environment through which water can be gained or lost to the surrounding substrate. (Tucker et al, 1978).

Mortality factors;

The primary predatory attacks on box turtles are during the egg stage. Ants, snakes, raccoons, skunks, crows, and dogs all feast on turtle eggs (Dickinson, 1953). Research on success of turtles nestlings show that inundation of nest sites may be one of the most important factors governing mortality of aquatic turtle embryos. Plummer (1976) discovered that nest sites in sandbars along the Kansas River suffered high mortality when river levels rose during incubation periods (River levels were primarily controlled by dam output on the Kansas River, and not directly correlated with rainfall). Eggs were found to withstand short perids of inundation without harmful effects, but inundation exceeding two days in early embryonic stages drastically decreased chances of normal development (Plummer, 1976). The main effect of flooding was suffocation of developing embryos and hatchlings. Embryos obtain oxygen by diffusion of gases through pores in the egg shell but this is impossible when eggs are covered by water. In addition, excessive rainfall lowers the ambiant temperatures of the nest cavity, thereby increasing the incubation period by slowing development. Longer incubation periods increase the chances that predators will locate nest sites (Kraemer and Bell, 1980).

Marking turtles;

Each new turtle found was marked by a code system originated by Cagle (1939) (See Appendix A). Markings are permanent so that recognition from decade to decade is possible. A permanent marking system is necessary when studying population dynamics of long-lived species such as turtles. The Ernst system (1974) for permanently marking turtles is similar to the Cagle system but differs in the manner of numbering of the marginal laminae that are marked. The Cagle system uses codes to provide a reference point for later identifying the number of a marked turtle. In contrast, the Ernst system uses codes which spells out numbers providing instant identification of a turtle, overcoming the complexity and non-consecutiveness of the Cagle system. However, the Ernst system necessitates more code marks than the Cagle system, even at low numbers (Smith and Chiszar, 1975; Ernst, Hershey and Barbour, 1974).

Sexing and sex ratios;

Upon maturity, turtle species develop secondary sex features which can aide researchers in determining the sex of individual turtles with relative accuracy. To determine sex with certainty, examination of internally located gonads is required. However, this procedure requires sacrificing animals. Use of secondary sex characteristics, rather than dissection, is advisable whenever valid sexual dimorphic features have been discovered (Harless and Morlock, 1979). Acceptable means for externally sexing juvenile turtles are not yet available. Features useful for sexing eastern box turtles have been established (See Appendix A).

An unequal adult sex ratio with extreme female bias has been reported for various species of turtles. Forbes (1940) found the most notable deviation of 1:5.9 for Diamondback Terrapin (Malaclemmy centrata). Other researchers; Sexton (1959), Cagle (1950) and Risley (1933), have also claimed a female bias, but according to Gibbons (1970), data was influenced by faulty methodology, sex identification or selective sampling. Other studied species show a variety of sex ratios with an overall average showing a slight female bias of .96:1 (Harless and Morlock,1979). After analyzing sex ratio data from Stickel (1950), Reagan (1974), Schwartz and Schwartz (1974), Leuch and Carpenter (1981) found no significant deviation from a 1:1 sex ratio among populations of box turtles. Stickel (1978) reported a decline in proportion of females over 20 years of age during a 30 year time span. Leuck and Carpenter (1981) questioned the determination of sex ratio using only those individuals over 20 years of age. However, unless there is differential mortality of the sexes between the sub-adult and adult stages or unequal sex ratios at hatching, which has not been found, then sex ratio based upon individuals over 20 years of age should provide an accurate estimate of the overall sex ratio for the entire population in each age class.

The ratio of males to females in turtles may have considerable bearing on reproductive success

(Hilderbrand, 1929). Extensive experiments on Diamondback Terrapin (*Malaclemmys* sp.) have shown that egg fertility in females is higher when there is a higher proportion of males to females in experimental populations (Tinkle, 1961).

Environmental sex determination, which plays a role in the determination of sex ratios, is a unique characteristic of most turtles, including *Terrapene carolina*, and alligators. Environmental sex determination is a phenomenon in which the incubation temperature of an egg determines the sex of its developing embryo (Bull, 1980). All male broods are produced at one temperature extreme (22 to 28 C) and exclusively females at the other extreme (30-35 C). Broods consisting of both males and females develop, usually in a 1:1 sex ratio, within a narrow temperature range between the two extremes at about 29 C (Bull, Vogt, and Bulmer, 1982). Therefore, with environmental sex determination the sex ratio is determined by two factors, a) the mothers choice of nest site, b) the embryo's sex differentiation in response to temperature (Bulmer and Bull, 1982).

Estimating age;

Nichols (1939) plotted carapace length against known turtle ages for*T. carolina*to derive a curvilinear relationship. Elghammer et al (1979) represented this relationship in the two following equations:

$$\frac{Y}{100} = 1.3 - e^{0.1x} \qquad \text{eq. 1}$$

$$Y = 30x^{0.36} \qquad \text{eq. 2}$$

(Y= carapace length; x= age in years)

The second equation is considered a more reasonable predictor of age from carapace length; however, it is recognized as a crude approximation. Using these equations, Elghammer et al (1974) derived at the following estimations of mean age for T. carolina: 70 years for males (range 50 to 100); 60 years for females (range 16 to 122).

Growth rings of the scutes can also be used to estimate the age. Elghammer et al (1979) found that ring counts were technically difficult, and had strong reservations about its interpretation. Cagle (1944) estimated age of turtles using this method, but considers the techique only reliable under conditions of rapid shell growth. The period of rapid growth for box turtles occurs before the years of 18 to 21. Therefore, quantitative analysis of growth lines provides a reasonable approximation of age for individuals still growing (or younger than the 18-21 years age bracket). Turtles with greater than 18-21 growth rings are then simply categorized as more than 20 years old (Stickel, 1978). Long term population studies, such as this study, will provide more accurate approximations of life span forT. *carolina* and other long lived species.

Geographical range;

The genus*Terrapene*consists of mostly terrestrial dwellers of the primarily aquatic family Emyidae. Two species of box turtles, *T. carolina* and *T. ornata* (western box turtle), are found in the United States. *Terrapene carolina* ranges from Southeast New Hampshire to Florida, west to Michigan, Illinois and Tennesse. *Terrapene ornata*, a turtle of the plains and prairies, ranges from Indiana to Southeastern Wyoming, south through Texas and into the coastal prairies of Louisiana (Conant, 1958).

Sixteen species of turtles are indiginous to the state of Maryland. The eastern box turtle is the only truely terrestrial species of the 16 native species. Two of the species, *Clemmys muhlenbergi*(bog turtle) and *Clemmys insculpta* (wood turtle), are considered semi-terrestrial; however, they are endangered and uncommon, respectively, in Maryland (Norden, 1984).

Home range;

The home range concept is viewed as a valid and useful measurement. However, disagreement often occurs among those who have attempted to define and estimate the actual area. Studies that determine home range size contribute to the understanding of a number of ecological processes: a) providing an indication of the size of an area necessary to sustain a breeding population of the given species; b) the degree of intraspecific overlap of home ranges indicates the social structure or tolerance of the population (Harless and Morlock, 1979). c) home range size, along with population density "constitutes an expression of the status of the population and an index to the suitability of the environment" (Stickel, 1950).

Defining home range has created controversy among individuals studying the topic and slightly different definitions have been formulated for a large number of home range studies. Three definitions are reviewed here. Stickel (1950) defined home range as 'the area over which an animal normally travels in the course of its daily activities.' Jennrich and Turner (1969) specified the definition as the area of the smallest subregion that accounts for a specified portion (i.e. 95%) of its total utilization. Burt (1943) formulated the most noted definition; 'the area traversed by the individual in its normal activities of food gathering, mating and caring for young. Occassional sallies outside the area, perhaps exploratory in nature, should not be considered part of the home range.' In contrast, the definition of territory appears relatively uniform within the scientific literature. Territory is any defended area, be it the entire home range or only a portion of it (Noble,1939; Burt,1943; Stickel,1950). Home range of box turtles frequently overlap one another suggesting that box turtles do not maintain a territory (Stickel, 1950). To summarize the home range, territory concept, all animals have home ranges whether stationary or shifting. However, only those species that protect some portion of home range by fighting or aggressive behavior can be categorized as possessing territory (Burt, 1943).

Methods used for estimating home range size vary as greatly as the definition. The various methods often concludes different results for the same data. However, individual estimates using a given method for one species usually possess similar statistical magnitudes of error, enabling intraspecific comparative analysis of home range (McNab,1963).

One of the simplest methods used for estimating home range size is the minimum area method. Home range, with this method, is represented by the area of a convex polygon drawn by connecting the outermost points of detection (Mohr, 1947; Southernwood,1966). This method is graphically simplistic, and exhibits good statisical stability, but is biased in accordance with sample size (Jennrich and Turner,1969). Variations of the minimum area method are available: a) Home range is represented by the convex polygon, drawn by using minimum area method, plus a boundary strip of one half the distance to the next trap (Stickel, 1946a); b) Home range is calculated under the assumption that the greatest distance between points of capture constitutes the diameter of a circle which represents the animals home range (Stickel, 1946a, Fitch, 1947).

The modified minimum area method determines the outer boundaries of the home range of an animal by using one quarter the length of the distance between the two points of capture that are farthest apart. Capture points farther than one quarter of this range length from any other capture point are excluded from the main home range area. Instead, these points are connected to the closest point, within the home range, by a straight line, designating a one foot wide ban (Harvey and Barbour,1965). Fitch (1958) developed an additional method that is advantageous for approximation of home range size when only limited amounts of recapture points are available. This method uses the average distance between recapture points for estimating the radius of the home range.

Possible factors governing home range size;

There is considerable controversey with regard to the factors which influence the size of the home range. Some of the factors that may govern range size:

1) Body size: The size of the home range is related

to the body mass of the inhabiting animal. Larger species, which possess a greater energy demand, require a larger area for gathering food (unless food exists in superabundance) (McNab,1963). McNab estimated the power function relating home range size to body mass as an exponent of 0.63 for mammals. In contrast, Baker and Mewaldt (1979) found an exponent of 1.31, as well as Harestad and Bunnell's (1979) similar estimate of 1.36 (both for mammals). McNab's low exponent estimation is believe to be a result of a lower percentage of carnivores in his data set than Harestad and Bunnell's. Carnivores, requiring larger home ranges, have greater exponents relating range size to body mass. Therefore, trophic status may influence home range size to a greater degree than body mass (Jenkins, 1981).

2) Trophic level: Predatory species require greater range than those that gather or forage (McNab, 1963). Harestad and Bunnell (1979) suggest that larger animals may be "forced to include larger patches of relatively unproductive habitat in their home ranges than smaller animals." This is due to density of "accessible and acceptable food" decreasing with increasing body mass and trophic level. Therefore, food density, distribution and abundance appear to be more critical determinants of home range size than the type of food eaten. Granivores and carnivores, requiring scarce food sources

such as seeds and animal matter are shown to have greater ranges than herbivores and omnivores (Baker and Mewaldt,1979).

3) Metabolic rate: Mace and Harvey (1983) tested the correlation between home range size and daily energy expenditure. No significant relationship was found between the two. However, if rate of metabolism is a critical determinant, then adverse environmental conditions, which increase daily energy expenditure, would be expected to influence range size (McNab, 1963).

4) Inferior habitat: In very poor habitats, the energy expenditure needed to acquire food may exceed the energy value of the food. Inferior habitats may also lack provisions of food and shelter within a reasonable distance of each other (Stickel, 1950). Factors of inferior habitat, such as deficiency or over abundance of water and poor soil conditions influence home range size through action on the distribution and abundance of plants (food density). For example, desert mammals require greater range areas than their woodland counterparts (McNab,1963).

5) Population density: Species requiring large home ranges typically cannot maintain locally dense populations due to the greater demands for survival by such species (McNab, 1963). Hence, range size has a tendency to be smaller in densely populated areas than in

sparsely populated ones (Stickel, 1950).

Home range of *Terrapene carolina*:

Home range of the eastern box turtle is typically shaped in a circular fashion. In the following cited literature, home range represents the average maximum diameter of home range. Stickel (1950) found the mean home range to be 100.58 meters diameter (+7.92 meters SE) for male box turtles and 112.78 meters diameter (+8.84 meters SE) for female box turtles. The difference between range size of males and females was not significant. Dolbeer (1969) calculated average home range diameter of box turtles in Tennessee as 74.4 meters Home range of box turtles in Missouri was estimated at less than two hectares (Kiester et al, 1982). Nichols (1939) studying box turtles near his home in Long Island found the normal diameter to range 201.17 meters.

Eastern box turtles show distinctive homing instincts when removed from their home range through experimental and natural (flooding) means. Immediately following periods of flooding, surveys were performed at the Patuxent study site. Individual turtles, in which home ranges were previously known, were found a maximum of 204 meters from the nearest portion of their normal home range. Eleven days after the flooding, the turtle displaced the greatest distance was once again located within its normal range (Stickel, 1948).

Experimental displacement of a number of representative turtles was performed to determine the box turtles homing techniques. Movements of turtles placed outside their established home range consisted of an initial erratic movement (less than 10 meters) followed by unidirectional travels to the vicinity of the individuals home range (Posey,1979). Periods of unidirectional movement may be locally interrupted by obstacles along the pathway and inactivity at night (Lemakau, 1970). Natural and man-made guidelines provided by physical features such as woods, field edges, roads and streambeds are often followed during the course of their movements (Lemkau,1970; Posey,19794). Celestial navigation is not evident when turtles are located in their normal range where surrounding topographic features are familiar (DeRosa and Taylor, 1982).

While a turtle is moving in unfamiliar territory, it often stops to observe its surroundings for a brief period before continuing on its trek. Accurate homeward movement largely disappeared during partly or completely overcast skies, indicating turtles do use a form of celestial navigation during their travels (Gould, 1957).

A second form of long range, unidirectional movement occurs among transients. Transient turtles move more or less continuously through an area without recrossing any of the area passed through previously. It is believed that these occassional long-distance migrants play a role in "maintaining genetic similarity among populations and aide in spreading beneficial genes" (Kiester et al,1982; Vance, 1985).

OBJECTIVES

This study was undertaken to learn about changes in a local box turtle population that has been under surveillance since 1945. The objectives were:

1. To determine population and home range sizes of the eastern box turtle population at the Patuxent Wildlife Research Center's floodplain and compare the findings with those of previous studies on the same area.

2. To analyze habitat types and components of habitats used by the box turtles to determine preference and requirements by the species. Results will provide guidelines for park and wilderness management of box turtle habitat.

3. To determine changes that have occurred to the study area and its surroundings for hypothetical correlation with population trends.

METHODOLOGY:

Description of the area;

The Patuxent Research Refuge near Laurel, Maryland consists of 1073 hectares of primarily wooded land along the Patuxent River. The study area was located in the floodplains of the River. (See figures 6 and 7). The entire floodplain area is woodlands divided and opened by a network of tributaries and dried streambeds which provide natural drainage channels for the Patuxent River. Additional openings in the canopy are created by fallen trees which often carry along masses of grapevine and poison ivy upon falling. These lianas often form large dense mounds of debris which provides extensively used protective cover for box turtles. Flooding scours the study area following heavy rains, especially in the spring. Strong currents sweep through natural drainage channels in contrast to normal conditions when they stand dry or contain a shallow stagnant body of water. From July through November, unnatural flood conditions occur during dry periods when floodgates to upstream dams are opened, sending raging floods through the study area. Trash carried downstream during the floods litter the entire area. Leaves, sticks and other debris moved by the floods' energy at the base of trees, providing additional cover used by the box turtles.

Survey methods:

The United States Geological Survey surveyed the entire Patuxent Wildlife Refuge in 1940, placing numbered cement markers at 110.58 meter intervals, thus dividing the entire area into 1 hectare plots. During the present study transect lines using florescent flagging were placed at 6 meter intervals providing a field grid pattern joining cement markers.

Capture of turtles occurred during systematic, standardized census trips in which effort was made to cover the area thoroughly and uniformly. Each trip to the study area consisted of approximately 6 man hours surveying two of the 1 hectare plots. Surveyors systematically walk parallel to the transect lines intensively searching around all vegetation, logs and debris. The 1984 survey season was aided by a dog trained in using its superior sense of smell to locate turtles. Capture locations were recorded using compass readings and paced distances with reference to the cement (permanent) markers. Capture data is used to estimate population and home range size, based repeated captures.

Records on each turtle located include: date, time of day, habitat type, components of habitat, dominant floral species, behavior, age, size, sex, and given code.

Habitat recordings;

Upon location of a turtle, dominant features of the turtles' surroundings are noted. Prevelent floral species, woody and herbaceous, were identified and recorded. Five separate and unique habitat types within the floodplain and five components of habitat used by the turtles were identified. Each turtles immediate surroundings were observed for categorization of its habitat type and component of habitat. The following is a detailed discription of the five habitat types:

1) Dried Streambed: This is an elongated opening in the woods which provides a natural drainage channel for the Patuxent River during high waters. Typically the area is slightly muddy with only occassional stretches of standing or running water within the channel. The canopy is open along the dried streambed allowing constant sunlight to the area. Leaf debris is usually not present due to removal by occassional running water; therefore, providing a muddy surface most of the year. Fallen logs and vine debris within the channel is typical.

2) Open Woods: This is woodland area with sparse amounts of underbrush and understory. Existing underbrush is typically low, small herbs. Soil covering is provided by decaying leaf debris. The canopy shades the entire area allowing only small amounts of sunflecks to the woodland floor on sunny days.

3) Woods With Thick Underbrush: This woodland type has dense concentrations of underbrush and vine debris. The canopy is not as full as the 'open woods' category; however, it still filters most sunlight allowing only sunflecks to the woodland floor.

4) Woods Opening: These are area of the woods with openings in the canopy greater than three meters in diameter. Constant sunlight on sunny days floods the woods floor. Typically, down trees and vines as well as tall (approximately one meter) herbaceous vegetation cover the ground.

5) Swamp: These are extremely muddy areas with standing water several inches deep in many places. Sparse amounts of woody species dot the area. The open canopy provides considerable sunlight at ground level. Grasses and nettles occur in the underbrush. Logs are found scattered throughout.

Description of the identified components of habitat are as follows: Turtle were located...

1) in Vine Area: Underneath a dense maze of vine material at ground level.

2) Under a Log: Up against or underneath a down tree or decaying log.

3) Under Dense Vegetation: Within a dense concentration of tall (one meter or greater) herbaceous vegetation.

4) Out in the Open: Totally clear of all obstacles (living and nonliving) in the area.

5) In a Form: A cavity excavated by a box turtle in a superficial layer of leaves, debris, low dense vegetation or soil.

Home range:

Size and location of home range was determined by the use of two techniques: repeated captures and a trailing device. Calculation of range size based upon captures was used for any turtle found three or more times in the 1984 and 1985 survey seasons. Two methods for calculating home range were used: 1) range length method, where the greatest distance between points of capture constitutes the diameter of a circle representing the animals home range; 2) convex polygon method, where the outer most points of detection are connected producing a convex polygon. Stickel (1950) calculated home range by the range length method. Present home range estimates were, therefore, calculated using this method so that comparison of range size was possible. The second method, convex polygon, was employed for present home range calculations, because it is considered a more accurate method of estimating range size.

An even more accurate estimate was obtained by using a trailing device placed on eleven representative turtles. (Figure 11). The trailer was made from a six ounce can cut to fit smoothly on the carapace of an individual turtle. Two wire hooks to hold the copper wire spindle, and a guide loop for the thread were soldered to the inside of the housing. A 320 meter spool of white thread was placed on the spindle. The device in entirety was fastened on the turtles back using duct tape. The end of the string was tied to a solid object, such as a log. The turtle is then left free to partake in its daily activities for a period of twenty-four to fourty-eight hours during which the spool unwinds mapping out the turtle's route. By following the thread, individual turtle travel routes were plotted on graph paper in the field with note of compass readings and paced off distance traveled in each compass direction. Exact daily travels for the eleven turtles were obtained for periods ranging from two days to eleven months. The overall map of the daily excursions of each turtle provided an accurate, precise estimate of home range size (See figures 8 and 9).

Three turtles were followed in Autumn of 1984 during which a hibernation site was chosen. Chicken wire fencing two and one half feet high was placed around each hiberniculum in hopes of catching the three monitored turtles exit in spring. All three were caught leaving its hiberniculum in April and travel monitored for the spring months of 1985. The devices were removed from the turtles at the end of the study.

RESULTS

Home range;

From repeated capture data home range was determined by range length and convex polygon methods. Home range diameter calculated by range length method was 96.6 meters (+ 11.9 meters SE) with a range of 40.2 meters to 173.9 meters. The area of this average range size is 0.73 hectares. Home range area estimated by the convex polygon method was 0.20 hectares with a range of 0.02 hectares to 0.45 hectares. More detailed home range estimates obtained by the thread trailer method was 0.96 hectares with a range of 0.10 hectares to 3.17 hectares.

Habitat type;

The Chi Square test was used to determine preference of habitat type. The null hypothesis for box turtles use of habitat type is: the abundance of turtles found in each habitat type is proportionate to the area encompassed by each habitat type in the study area. The alternative hypothesis to the above statement is: the abundance of turtles found in each habitat type is not proportionate to the area encompassed by each habitat type in the study area. The area covered by each habitat and the number of turtles found in each area is as follows:

1) Study-area in 1984:

a) Dried Streambed: 2.23 hectares; 31 turtles
b) Open Woods: 3.24 hectares; 20 turtles
c) Swamp: 1.52 hectares; 8 turtles
d) Woods with Thick Underbrush:3.04 ha;10 tur.
e) Woods Opening: 1.11 hectares; 22 turtles

2) Study area in 1985:

a) Dried streambed: 2.83 hectares; 47 turtles
b) Open Woods: 4.05 hectares; 17 turtles
c) Swamp: 0; was not used in Chi Square estimate
d) Woods with Thick Underbrush:3.72 ha;2 tur.
e) Woods Opening: 1.21 hectares; 20 turtles

Based upon results from Chi Square testing, the null hypothesis for use of habitat type is rejected with a 99.999 % confidence level for both 1984 and 1985. Therefore, the alternative hypothesis is accepted suggesting that box turtles prefer some habitat types over others (See figures 1 and 2).

The Chi Square test was used to determine preference of components of habitat. The null hypothesis for box turtles use of components of habitat is: The abundance of turtles using each component of habitat is equal. The alternative hypothesis for box turtles use of components of habitat is: The abundance of turtles using each component of habitat is not equal. Based upon results from Chi Square testing, the null hypothesis for components of habitat is rejected with a 99.999 % confidence level for both 1984 and 1985. Therefore, the alternative hypothesis is accepted suggesting that box turtles prefer specific components of habitats (See figures 3 and 4).

IV. POPULATION SIZE AND SEX RATIO:

TABLE A: OBSERVED NUMBER OF TURTLES AND SEX RATIO

YEAR	MAN HRS	DAYS	NUMBER OF CAPTURES	TURTLES	SEX RATIO F:M
1945	257	77	1002	284	122:107 (100:88)
1955	172	57	1184	291	118:121 (100:103)
1965	304	81	941	230	85:117 (100:138)
1975	236	75	443	117	35:62 (100:177)
1984	345.5	84	95	61	13:37 (100:285)
1985	232	34	87	58	12:29 (100:242)

Man Hours = Total number of hours spent surveying the study area in search of turtles.

Days = Total number of days spent searching for turtles.

No. captures = Total number of times all the turtles were found.

Turtles = Number of individual turtles found.

Sex Ratio = Total number of females versus males of turtles 20 years old and older.

Population size;

The Schnabel technique of estimating population size using repeated captures was used. This provides an estimate of the total population within the study area as opposed to the number observed provided in Table A. The 1984 study site, 11.13 hectares, contains an estimated population of 92 turtles. (8.30 turtles per hectare). The 1985 study site, 11.82 hectares, contains an estimated population of 105 turtles (8.92 turtles per hectare). (See tables 1 and 2; and figure 5).

Sex ratio;

Sex ratio for each study year between 1945 and 1985 were tested for deviation from an equal abundance of both males and females. The null hypothesis of sex ratios for each year is: sex ratios are 1:1; showing equilibrium between the number of males and females. The alternative hypothesis is: sex ratios are not 1:1; showing a skewed number of males versus females. Based upon results from Chi Square testing, the years 1945, 1955, and 1965 accepted the null hypothesis showing equilibrium of sex ratios during these years. The years 1975, 1984, and 1985 reject the null hypothesis with greater than 99.99 % confidence level. Therefore, the alternative hypothesis is accepted for these years suggesting that a skewed sex ratio has existed since 1975.

DISCUSSION

Home range;

Home range diameter estimates of the Patuxent population in 1945 were: 100.58 meters (+7.92 meters SE) for males and 112.78 meters (+8.84 meters SE) for females (range length method). The area for these estimates of diameter are 7945.37 meters and 9989.76 meters respectively. These estimates in comparison to the present study depict a small reduction in home range size over the past fourty years. Schwartz (1974) determined average home range for box turtles in Missouri as 1.54 hectares for males and 1.46 hectares for females. The average home range size calculated by the convex polygon method for Patuxent turtles was .202 hectares. As stated previously, the Schwartzs average range size based upon repeated captures were larger than estimates of average range size obtained by the thread-trailer method and radiotelemetry. However, the trailer method in this study resulted in an average home range estimate 4.72 times greater than range estimates by repeated captures. The differences noted between the two studies are possibly a product of different average number of recaptures of each turtle (3 recaptures/turtle for this study; approximately 5-7 recaptures/turtle for the Schwartzs' study). In addition, the trailer device provides information on the specific daily travels of the turtle. Radiotelemetry and repeated capture data provides points of location, but no information is obtained for the turtle travels between these capture points. Therefore, the estimate of .955 hectares obtained by the trailer method, may be a more accurate estimate of the box turtles true range size at the Patuxent study site.

In the literature survey, five factors governing home range size were discussed. Two of the five; body size, and trophic level did not change for the studied population. Population density is a third factor that may influence home range size. In theory range size tends to be smaller in densely populated areas. However, the Patuxent population of box turtles is on a steady and drastic population decline (Turtles column in Table A). If population density was governing this population, the home range should have increased between 1945 and 1985 during which the population size was rapidly decreasing. However, range size during this period decreased.

Metabolic rate, daily energy expenditure, was hypothesized by McNab (1963) to increase under inferior habitat, therefore, increasing range size. Since home range has remained relatively stable, deterioration of the study-area habitat over the past four decades does not seem probable.

Two turtles in 1984 were observed each using two seperate seasonal home ranges. Both used a dry wooded area during fall, winter and spring. Summer was spent approximately 122 meters away in one of the swamps. Use of the swamp area directly corresponded with the hottest period of the year, July and August.

Population size;

The Patuxent floodplain study-site harbors approximately 8.6 turtles per hectare according to the results from the Schnabel method of estimating population size. Stickel (1950) determined that the density of turtles per hectare to be 10.6 in 1945. Only adult turtles found two or more times were used to obtain this estimate. Results from the present study using Stickel's method (Total number of adults found two or more times) are approximately 3.95 turtles per hectare in 1985. The size difference between 1945 and 1985 estimates depict a drastic decline in the density of turtles within the study site. This coincides with the reduction of the number of turtles found during the course of each study since 1965. Possible influences of this decline are suggested at the end of this discussion.

Schwartz and Schwartz (1974) also noted a decrease in population density during their nine year study. Estimates of 34.6 turtles per hectare at the onset of their study steadily declined to 17.3 turtles per hectare by its culmination. The initial density may have resulted from logging three years prior to the beginning of the study. Logging opened the forest canopy while the downed tree tops provided a variety of hiding places for the box turtles. As the canopy closed and tree tops decayed, habitat capacity for box turtles probably dwindled; influencing turtle population density in the area.

Habitat types and components of habitat;

Two habitat types, `dried streambeds' and `woods opening' composed the smallest proportion of acreage (with the exception of `swamps' in 1984). In addition, the greatest number of turtles were found in these two areas; showing a considerable preference for dried streambeds and woods opening. (Figures 1 and 2). Both habitat types typically have an open canopy allowing constant sunlight into the area on sunny days. Turtles were often observed basking in the sun, even during extremely warm conditions, i.e. 35 C. These two habitat types also typically harbor mazes of logs, vine debris, and tall herbaceous ground cover. These three components of habitat were all used by the turtles, but the greatest preference was for logs to wedge against and hide under. The greatest number of turtles were found in the open (Totally clear of all obstacles in the area). Locating turtles standing in a clearing is considerably easier than finding turtles in forms, vine mazes or under logs. The high number of turtles found out in the open is possibly due to a bias observation technique and not a preference by the turtles.

Swamps, making up a small portion of the study-area, are used by box turtles during hot, dry spells. Eight turtles were discovered in July and August, 1984, seeking refuge underneath a pool of saturated mud. Long periods of time, as great as two weeks, have been spent motionless under the swampy pools. Greater numbers than observed may be aestivating in these swamps. However, location of turtles in these areas are extremely difficult, because the top of the carapace is often the only portion of the turtle exposed.

Schwartz and Schwartz (1974) observed a population decline, during the course of their nine year study (From 600 to 400 turtles in 22.27 hectare) They noted that certain land use practices may have had a positive but temporary impact on the population density. Three years prior to the onset of their research, the study-area was logged for stave bolts; leaving the upper trunks and crowns as piles of debris on the ground. The downed trees left openings in the canopy and provided cover close to the ground. No logging occurred during the nine year study permitting growth of the understory closure of the open areas by thick brush. Loss of these open areas may have been an influenial factor in the population reduction.

Management of parklands for the greatest box turtle population density may include:

1) Opening of forest canopy: Natural openings of the forest canopy are often created where trees have died or fallen. Maintenance of these areas is possible by periodic removal of saplings in the open area. Where a deficiency of these natural openings occur, the forest canopy can be opened by selectively removing one or two adjacent trees to create the small openings prefered by the box turtles.

2) Maintenance of logs: Logs are often removed from woodland floors for a number of reasons: to improve the aesthetics of the forest; reduce fire hazard; or for use as firewood. Box turtles, as well as a number of other vertebrates and invertebrates, extensively use such logs. Down trees are excellent hiding places and typically provide moist ground underneath. Removal of logs from parklands should therefore be prohibited except under unique and necessary circumstances.

3) Provision of vegetational debris: Parklands with deficient quantities of logs, vine masses and other vegetational debris can be supplemented. Clusters of vines, sticks and logs placed in woods openings and near moist areas, such as swamps, can provide the necessary

cover to increase an area's habitat capacity for box turtles.

Sex ratio;

A drastic decline in population size has been accompanied by a reduction in proportion of females to males. The slight female biased sex ratio (.96:1) noted in 1945 has steadily reversed to a considerable male bias (1:2.42) by 1985. Declining proportions of females to males is viewed as typical of a declining population (Stickel, 1950).

Habitat;

The woodlands of the study-area have remained as a natural area since the original study in 1945. Succession has not been manipulated by man and principal plant species listed for the study area by Hotchkiss and Stewart (1947) remains unaltered today. The plant community includes:

TREES;

Carpinus caroliniana
Betula nigra
Fagus grandifolia
Fraxinus americana
Liquidamber styraciflua
Acer rubrum
Liriodendron tulipifera
Ulmus americana
Quercus palustris

SCRUBS/VINES

Lindera benzoin
Rhus radicans
Viburnum prunifolium

HERBS

Arisaema triphyllum
Erythronium americanum
Laportea canadensis
Claytonia virginica
Ranunculus abortivus
Podophyllum peltatum
Impatiens biflora
Viola affinia
Cryptotaenia canadensis
Galium aparine

The study site habitat is classified as mature forests consisting of trees 11 to 15 inches DBH. An understory of spicebush (*Lindera benzoin*), blackhaw (*Viburnum prunifolium*) and paw-paw (*Asimina triloba*) is present in both dense and sparce quantities throughout the area. Mature forests, plagued by disease, insects and wind damage, characteristically have many down trees and snags which open the canopy allowing sunlight to reach the forest floor. Dense quantities of herbaceous material, stimulated by the increase of light, is also a common occurrance in scattered areas of these mature forests. Pole stage forest, with an average of 5-11 inches DBH, lacks most of the above mentioned qualities. The dense canopy of the young trees filters sunlight resulting in a sparse understory and herbaceous groundcover.

Changes in habitat over the last 40 years are primarily a result of forest maturation. The study-site now possesses more of the typical characteristics of the mature forest than in the late 1940's. Each of these characterestics; opened canopy, downed trees, and increased groundcover, are all ingredients of prime turtle habitat. Therefore, the reduction in home range size of the Patuxent box turtle population may be a factor of the habitat improvements. The turtles basic requirements may now be provided within a smaller area than in 1945, resulting in smaller home range. Why, then, the drastic population decline since 1965 and 1975, during an era of improved habitat within the study site?

Changes to the surrounding area of the Patuxent Research Center have occurred: upstream water treatment plants have released chlorine into the river; the river has been polluted by run-off and other sources; reservoirs have impounded upstream water causing scouring floods when floodgates are opened; increased highway systems and residential communities in the vicinity have altered the surrounding habitat.

Large areas of the floodplain in the eastern coastal plain valley, such as the study area, are washed over periodically under natural conditions. This natural flooding occurs primarily in the spring months due to spring thaws and rains. Individual adult turtles display remarkable ability to remain in their home ranges despite flood conditions. Several individuals with known home ranges have been observed displaced during flood periods then later located again within their home range (Stickel, 1948). At the study-area, severe flooding occurs more frequently now since two reservoir impoundments were built in 1944 and 1949 several miles upstream from the study area. Floods inundate the study area through-out the year as opposed to primarily spring months under natural conditions.

I suggest that the noted population decline is due to floods causing increased mortality during the egg stage and among hatchlings. Flooding under natural conditions, occurring primarily in spring, does not interfere with box turtle eggs (June through September) and hatchlings (September and October). However, flooding induced by the opening of floodgates often occurs during the summer and fall months in the study-area, overlapping the incubation period and hatching time. Inundation of incubating eggs increases mortality.

A pronounced population decline was not observed until the decade between 1965 and 1975; approximately twenty years after dam construction. Turtles younger than twenty years of age are usually not located as readily as their elders. Therefore, increased egg mortality would not be noticed until twenty years after the onset of man-induced flooding, creating a twenty year time lag between actual population decline and observation of this decline.

Eggs subjected to prolonged periods of inundation experience decreased incubation temperatures. Since males develop from eggs incubated at cooler temperatures, a greater proportion of males should result when increasing numbers of clutches are flooded. Therefore, the significantly skewed sex ratios of the study population may have ultimately resulted from increased flood conditions in the study-area.

Recommendations for future studies:

The first recommendation is to determine, through experimental testing, if the box turtle population density at Patuxent is being influenced by artificial flooding due to upstream dams. Comparison of a turtle population found in the same type of habitat above and below the dams may yield some useful information. In addition, laboratory experimentation to test box turtle eggs abilities to withstand inundation for varied periods of time will help determine if the floods are smothering the eggs.

The second recommendation is to continue the presently successive study of the box turtle population each ten years. Extensive data for thousands of turtles since 1944 affords a unique opportunity to make break throughs in ecological studies. Answers to the questions of mans true impact on the environment may be provided by long-term studies such as this one.

APPENDIX A

TECHNIQUES OF ESTIMATING AGE;

Each scale on the box turtles carapace and plastron has growth rings. Each ring is believed to correspond to one year. Rings are counted starting in the center of a scale, working towards the margin. The first or center ring is not counted since it is present at hatching. Age of turtles with 20 or more rings per scale are recorded as 20 plus due to rings towards the margin of the scale being indistinguishable for accurate counting.

BODY SIZE MEASUREMENT TECHNIQUES;

Measurements using a caliber are obtained for carapace; height, length, anterior and posterior width; plastron; anterior and posterior length, width at the hinge and widest point. Measurements were taken only once per individual per survey season.

TECHNIQUES OF SEXING THE BOX TURTLES;

Sex of adults was determined by a series of secondary sex characteristics which distinguishes the sexes with relative accuracy.

See table below:

CHARACTERISTIC FEATURES USED IN SEXING EASTERN BOX TURTLES

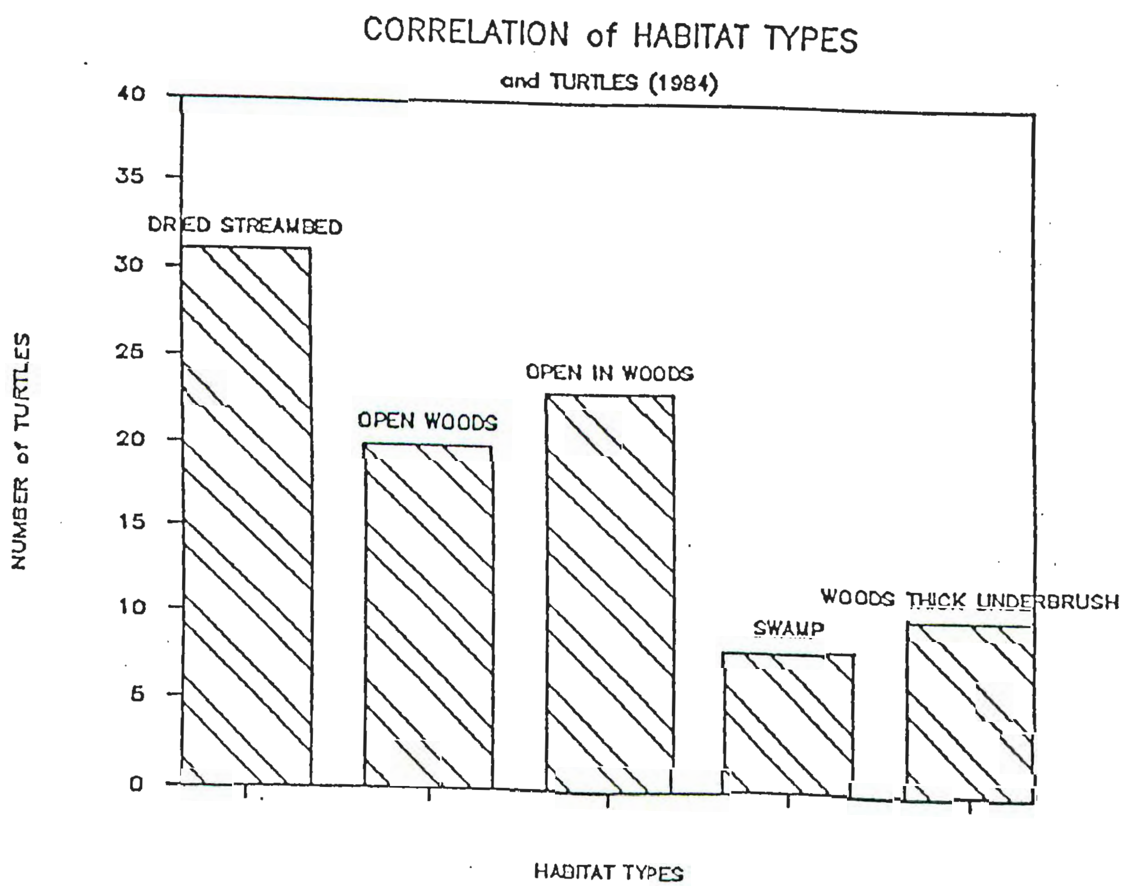
Characteristics	Male	Female
color of iris	red	yellow-brown
concavity of plastron	concave	flat/slightly concave
tail	long, stout	short, tapers
hind limb nails	short, curved	long,slender
plastron length	> 140 mm.	< 140 mm.
dorsal carapace	wide, flared	no flare

TECHNIQUES IN MARKING THE TURTLE;

Each turtle located was permanently marked for future identification by filing a series of notches on varied combinations of the marginal laminae or scutes. The notches filed were determined according to the Cagle Coding System. Beginning anteriorly, the marginals are numbered on each side from one to twelve. A series of four notches on four seperate marginals were used for 1984 and 1985 survey seasons. Marginals four through seven on both sides were not used as they form the carapace-plastron bridge. The code numbers correspond to the combination of marked marginals. Code numbers representing notches on the same side of the carapace are seperated by commas. Numbers designating codes on the left and right side are seperated by a hyphen. A "endless" array of code combinations can be formed using this system, and identification is permanent and easily read. Occassionally, injury to the carapace causing loss or severe chipping of the marginals interfered with the code, inhibiting absolute identification of the turtle (See figure 10).

APPENDIX B

Figure 1: Number of turtles found in each Habitat Type in 1984



CORRELATION of HABITAT TYPES
and TURTLES (1984)
40
35
30
25
20
15
10
5
0
NUMBER of TURTLES
DRIED STREAMBED
OPEN WOODS
OPEN IN WOODS
SWAMP
WOODS THICK UNDERBRUSH
HABITAT TYPES

Figure 2: Number of turtles found in each Habitat Type in 1985.

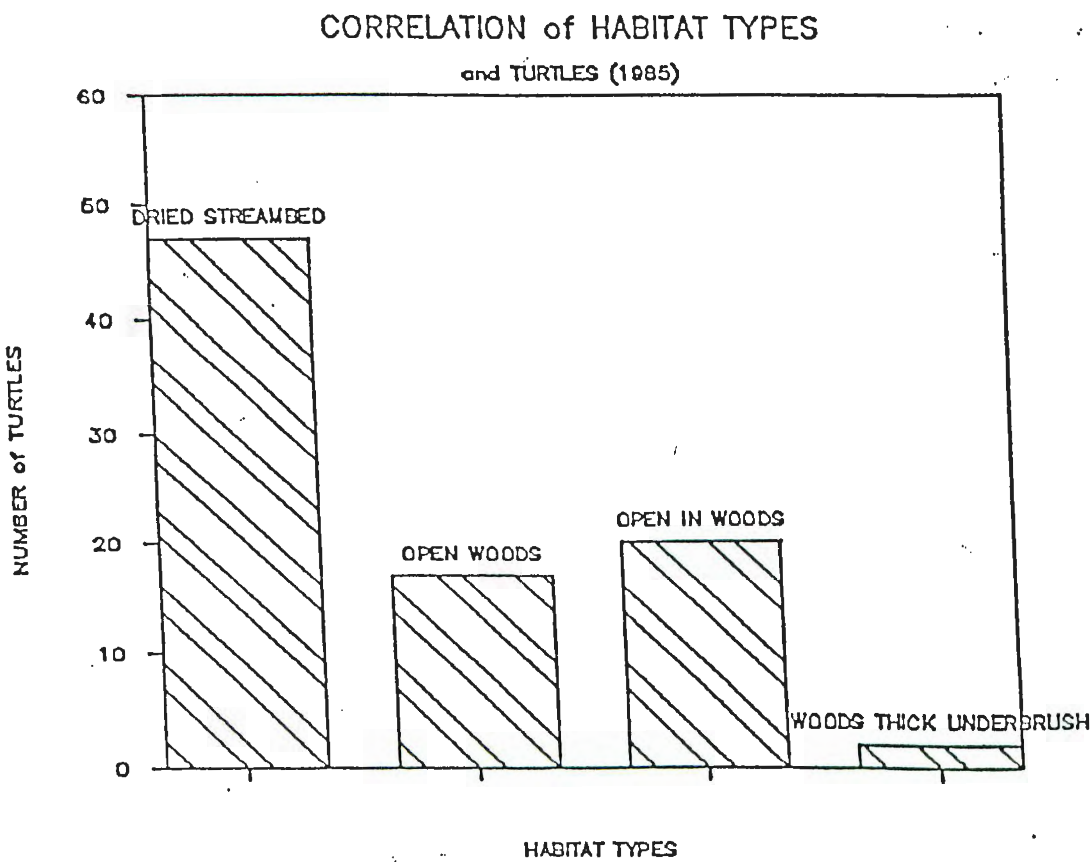
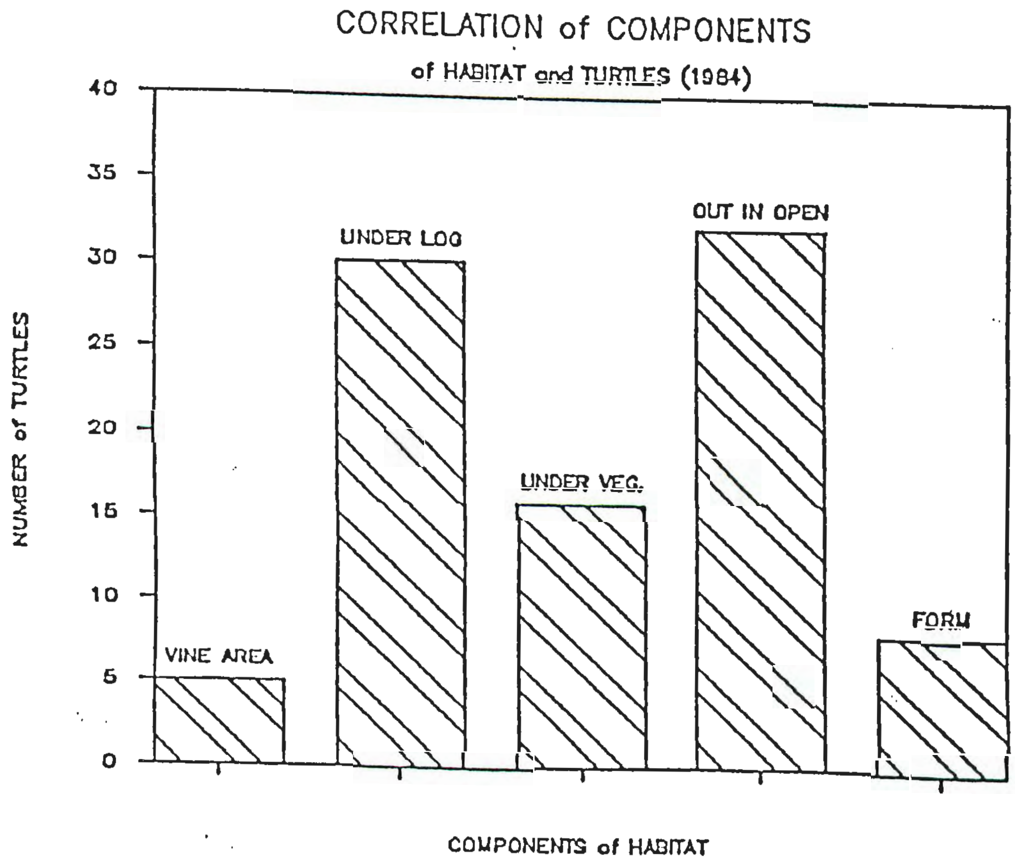
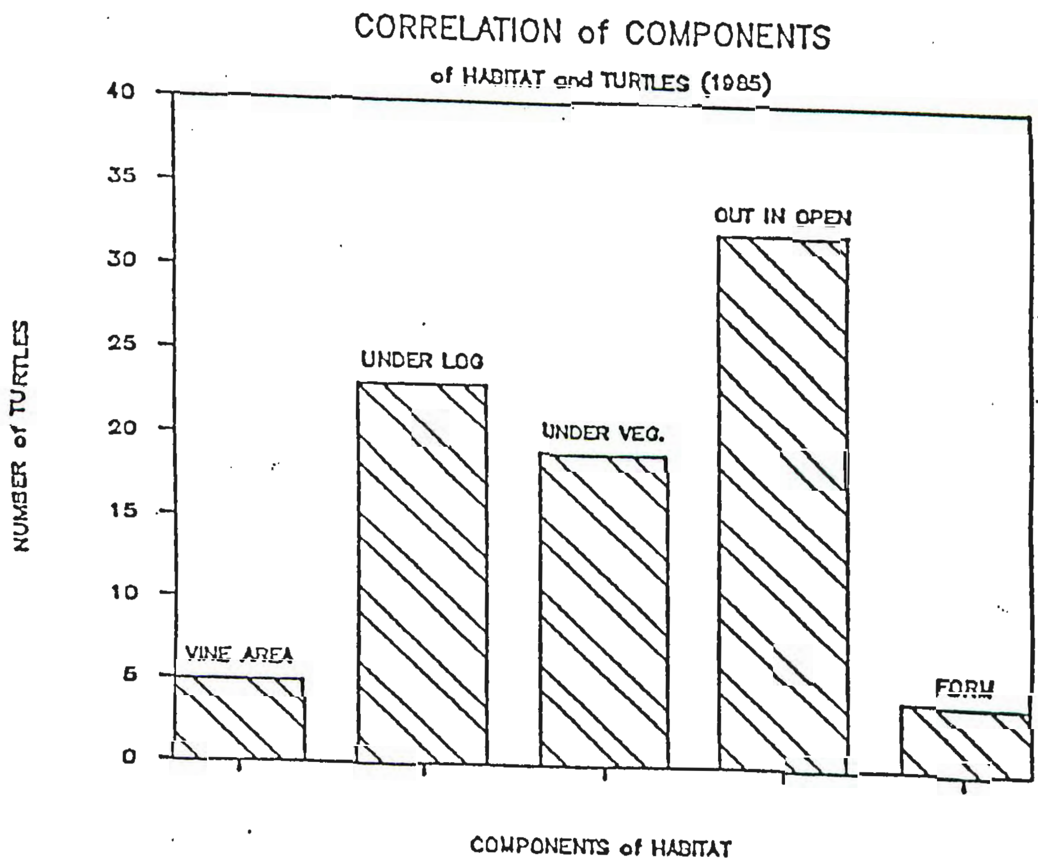

CORRELATION of HABITAT TYPES
and TURTLES (1985)
60
50
40
30
20
10
0
NUMBER of TURTLES
DRIED STREAMBED
OPEN WOODS
OPEN IN WOODS
WOODS THICK UNDERBRUSH
HABITAT TYPES

Figure 3: Number of turtles found in each Component of Habitat in 1984.



CORRELATION of COMPONENTS
of HABITAT and TURTLES (1984)
NUMBER of TURTLES
40
35
30
25
20
15
10
5
0
VINE AREA
UNDER LOG
UNDER VEG.
OUT IN OPEN
FORM
COMPONENTS of HABITAT

Figure 4: Number of turtles found in each Component of Habitat in 1985.



CORRELATION of COMPONENTS
of HABITAT and TURTLES (1985)
NUMBER of TURTLES
40
35
30
25
20
15
10
5
0
VINE AREA
UNDER LOG
UNDER VEG.
OUT IN OPEN
FORM
COMPONENTS of HABITAT

Table 1: Schnabel population estimate using mark-recapture data for 1984.

A = number captured in a day
B = number marked available for capture
C = number marked animals caught in one day

DAY	A	B	AB	C
6/9	1	0	0	0
6/12	3	1	3	0
6/13	1	4	4	0
6/16	1	5	5	0
6/17	2	6	12	0
6/20	3	8	24	0
6/23	2	11	22	0
6/24	2	13	26	1
6/28	2	14	28	0
6/29	4	16	64	0
7/1	4	20	80	1
7/2	3	23	69	1
7/4	3	25	75	1
7/6	3	27	81	0
7/7	3	30	90	1
7/9	1	32	128	2
7/14	4	34	102	3
7/16	3	34	102	2
7/17	4	35	140	3
7/22	1	36	36	0
7/23	1	37	37	0
7/24	4	37	148	2
7/26	2	39	78	0
7/27	1	41	41	1
7/28	2	41	82	0
7/30	1	43	43	0
8/2	1	44	44	1
8/4	2	44	88	0
8/5	4	46	184	4
8/6	2	46	92	1

Table for Schnabel population estimate continued (1984):

DAY	A	B	AB	C
8/11	4	47	188	3
8/13	2	48	96	1
8/16	1	49	49	1
8/18	1	49	49	1
8/23	1	49	49	1
8/25	1	49	49	1
8/26	1	49	49	0
8/28	3	50	150	0
9/2	2	53	106	0
9/3	2	55	110	0
9/9	2	57	114	1
9/11	2	58	116	1
9/15	1	59	59	0
9/22	2	60	120	2
9/29	1	60	60	0
9/30	1	61	61	0
10/13	1	62	62	1
10/19	1	62	62	0

Table 2: Schnabel population estimate using mark-recapture data in 1985

A = number of captured in a day
B = number marked available for capture
C = number of marked animals caught in one day

DAY	A	B	AB	C
5/22	4	0	0	0
5/28	2	4	8	0
6/2	2	6	12	0
6/3	1	8	8	0
6/9	4	9	36	0
6/10	2	13	26	0
6/12	4	15	60	0
6/16	4	19	76	0
6/17	3	23	69	1
6/19	1	25	25	1
6/24	6	25	150	1
6/26	1	30	30	0
6/30	3	31	93	1
7/1	3	33	99	1
7/7	4	35	140	2
7/8	3	37	111	0
7/14	3	40	120	2
7/15	4	41	164	1
7/17	4	44	176	2
7/21	2	46	92	1
7/22	4	47	188	2
7/24	4	49	196	3
7/28	3	50	150	3
7/29	3	50	150	0
8/4	4	53	212	1
8/5	1	56	56	0
8/6	1	57	57	1
8/12	1	57	57	0
8/14	2	58	116	1
8/18	2	59	118	2

Figure 5: Results from population estimates for 1984 and 1985 using the Schnabel method.

1984:

P = population estimate
A = number of captured in a day
B = number marked available for capture
C = number of marked animals caught in one day

$$P = \frac{(AB)}{C}$$

$$P = \frac{3509}{38}$$

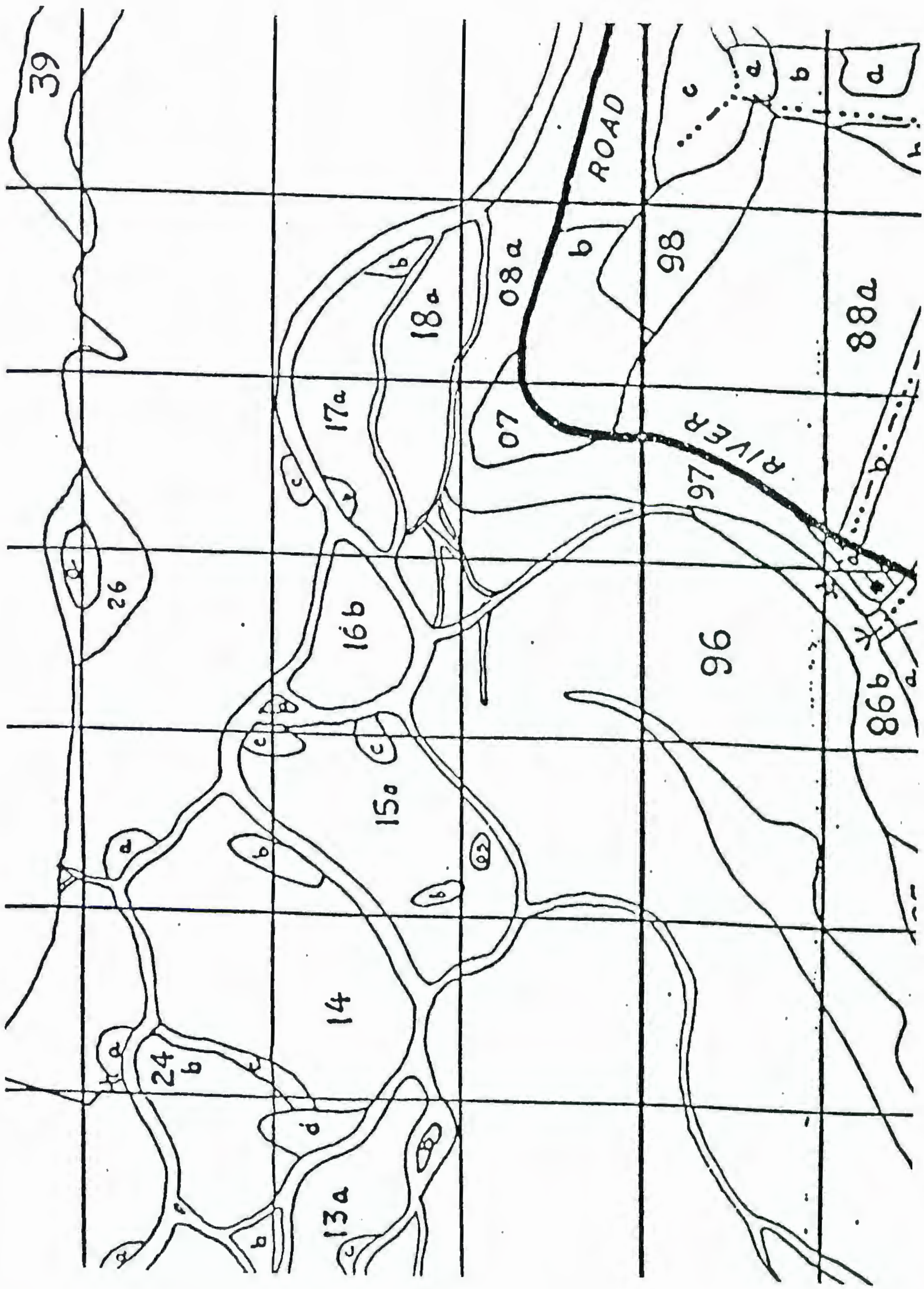
P = 92.342 eastern box turtles in the 27.5 acre study-area

1985:

$$P = \frac{2619}{24}$$

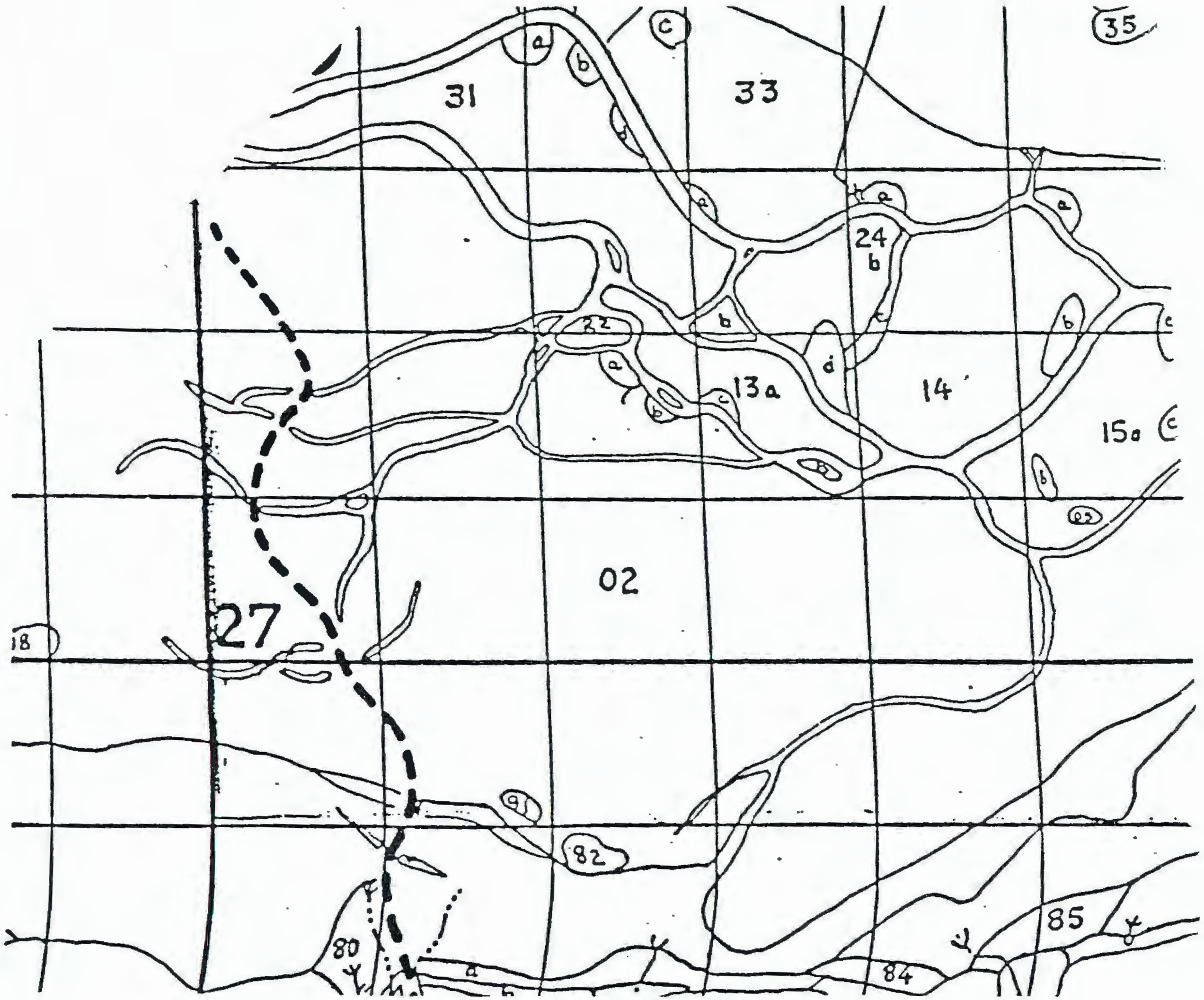
P = 105.269 eastern box turtles in the 29.2 acre study-area

Figure 6: Map of 1984 study-area.



39
26
ROAD
RIVER
98
08a
18a
17a
07
97
16b
96
88a
86b
15a
14
24
13a

Figure 7: Map of 1985 study-area.



35
31
33
24
b
22
13a
14
15a
02
27
18
91
82
80
85
84

Figure 8: This map shows the detailed travels of an adult female box turtle, number 16, from June 29, 1984 through June 1, 1985 (Data obtained by the thread-trailer method). The lines, representing the daily route of the turtle, stop and start at various points due to the string breaking and the turtle later found within its home range. Data of the turtles location is not available between July 24, 1984 through August 25, 1984 and September 22, 1984 through September 27, 1984 due to the string breaking, resulting in temporary loss of the turtle. The monitor was finally removed from the turtle on June 1, 1985, when the turtle was found crossing the Patuxent River.

Results from two methods of estimating home range are:

a) Range length method:

145.847 meters (diameter of the home range)

b) Minimum area method or convex polygon method:

32,273.91 $meters^2$

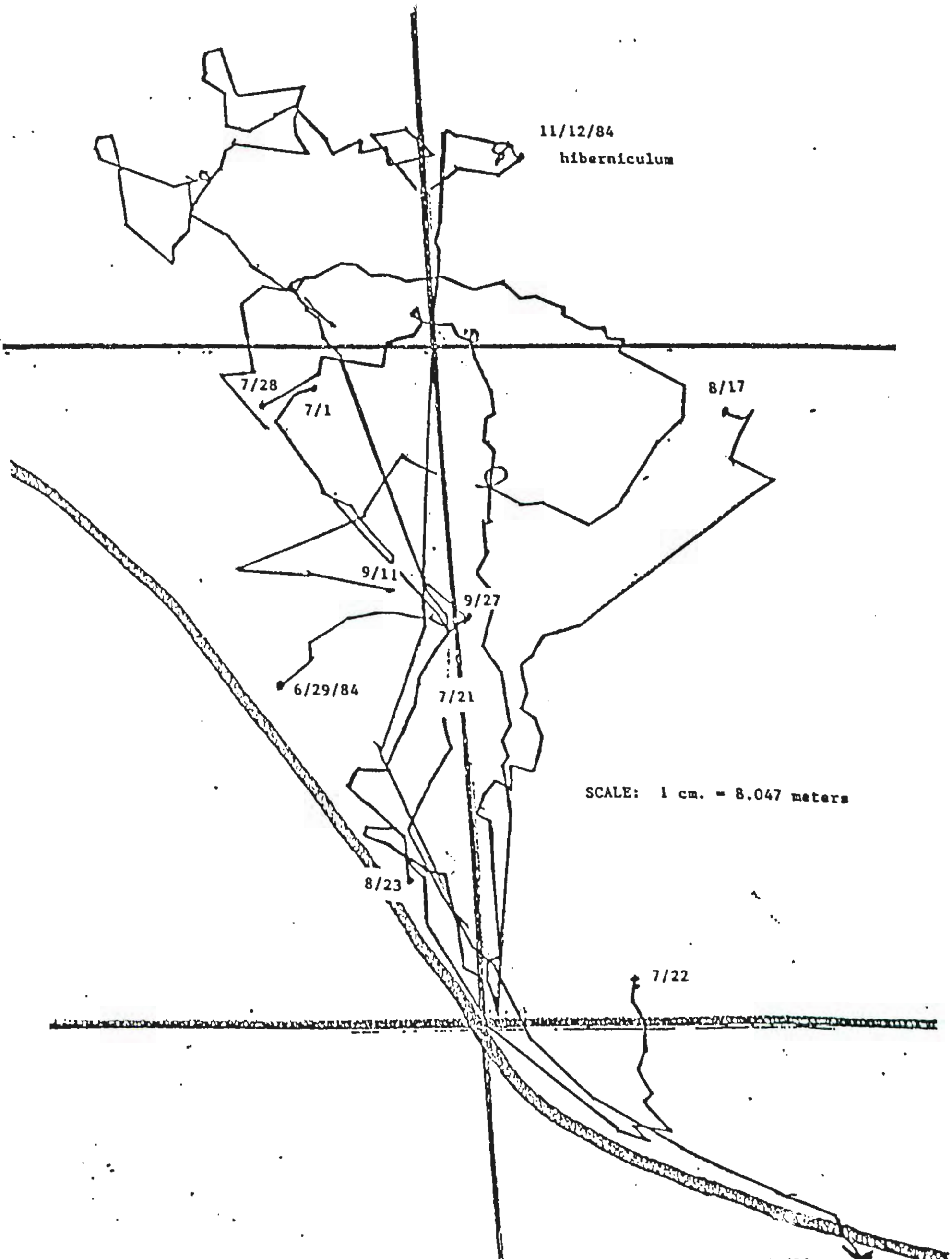

11/12/84
hibernaculum
7/28
7/1
8/17
9/11
9/27
6/29/84
7/21
SCALE: 1 cm. = 8.047 meters
8/23
7/22
6/1/86

Figure 9: This map shows the detailed travels of an adult male box turtle, number 33, from August 18, 1984 through October 30, 1984 (Data obtained by thread-trailer method). The lines represent the turtles meandering on each day.

Results from two methods of estimating home range are:

a) Range length method:

332.959 meters (Diameter of the home range)

b) Minimum area method or convex polygon method:

39,465.30 $meters^2$

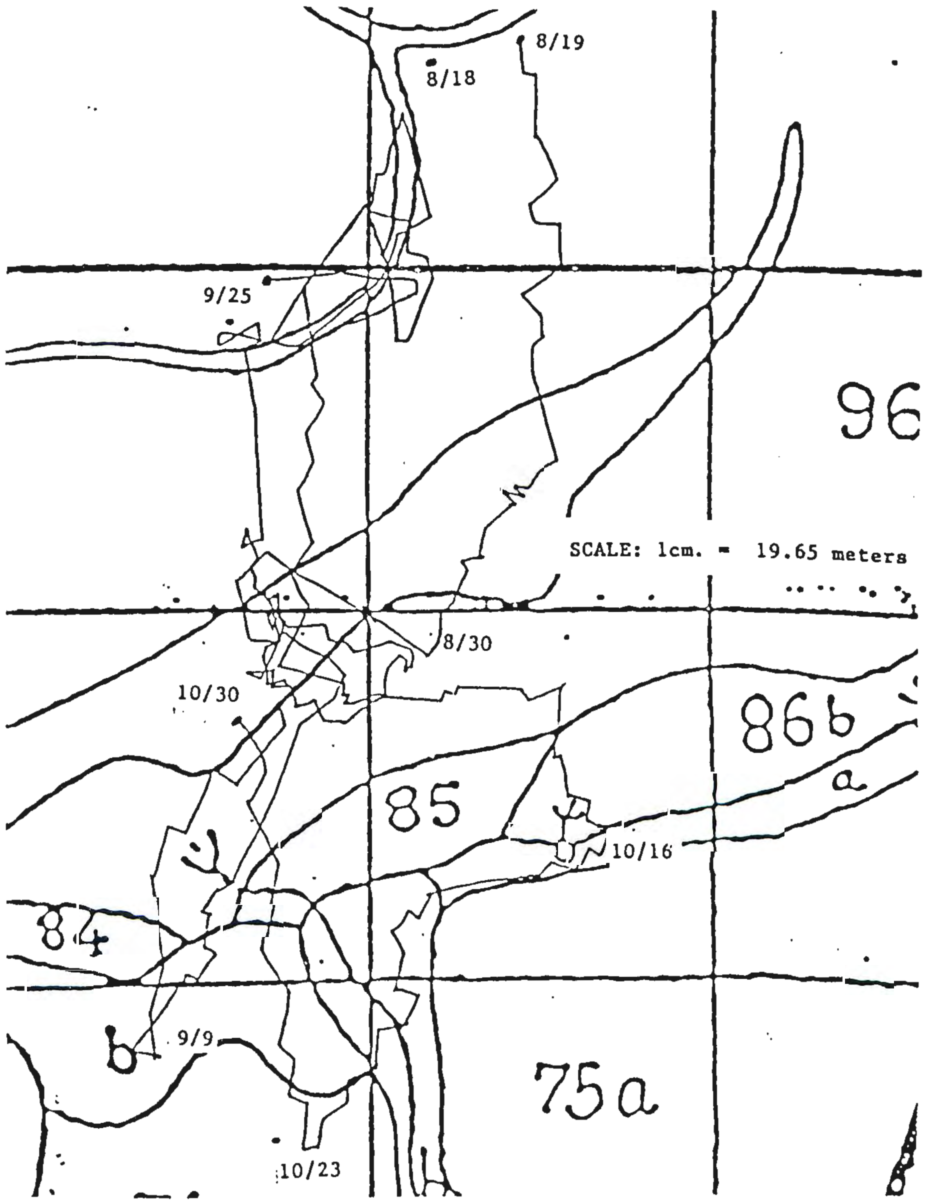
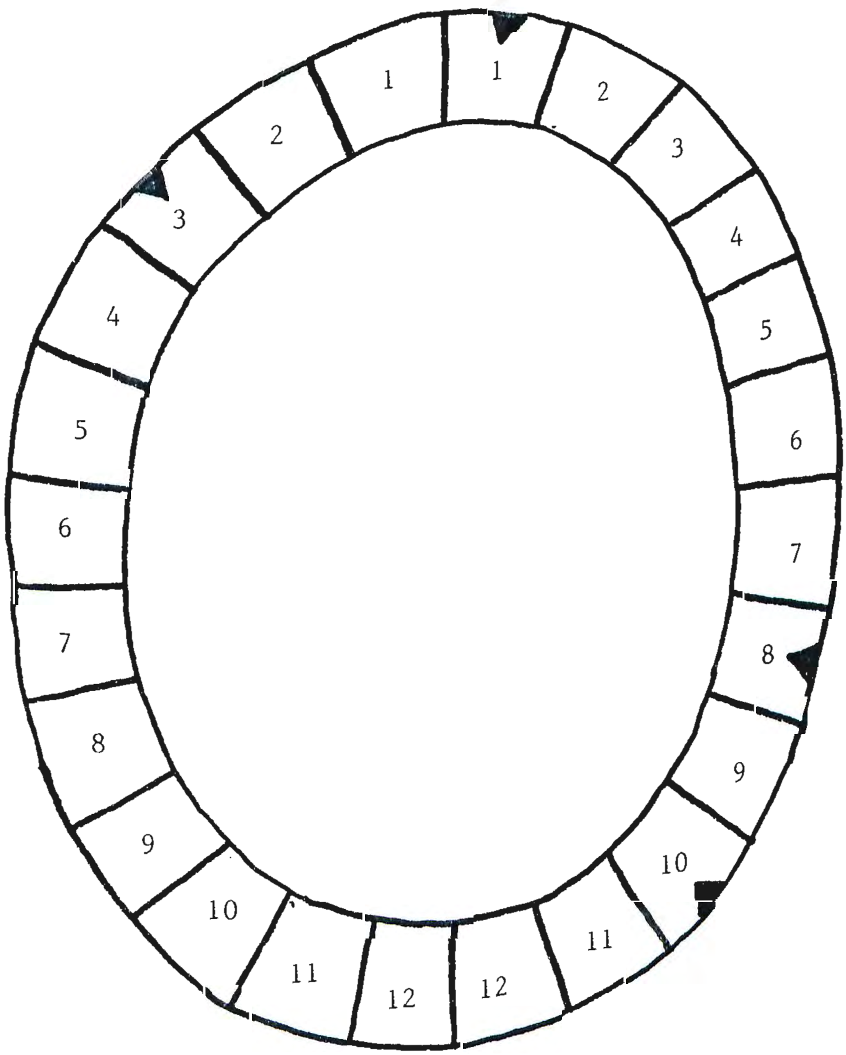

8/19
8/18
9/25
96
SCALE: 1cm. = 19.65 meters
8/30
10/30
86b
a
85
10/16
84
9/9
b
75a
10/23

Figure 11: The following are pictures of a turtle with an attached thread-trailer device.

Figure 10: This diagram depicts the carapace of a box turtle. The outer laminae on the right and left side are numbered through 12 starting at the head. scutes numbered 4 through 8 are not used since they form the bridge between the carapace and plastron. The code shown in this diagram is 3-1, 8, 10 (Saute number 3 on the left side, and scutes numbers 1, 8 and 10 are all filed).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