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ABSTRACT

POPULATION DYNAMICS AND ECOLOGY OF THE PAINTED TURTLE, CHRYSEMYS PICTA

by J. Whitfield Gibbons

A quantitative and descriptive analysis was made of the population dynamics and ecology of the painted turtle, *Chrysemys picta*, in southwestern Michigan. Individual growth rates, population structure, seasonal activity, and environmental conditions were determined for one population. Reproductive cycle and reproductive potential were determined for another. Integration of these data resulted in a quantitative and descriptive life history of the species.

One study population was in a marsh containing about 15 acres of open water. Survivorship and population size and structure were determined by a mark-release-recapture program over a two and one-half year period. More than 1000 *Chrysemys* were marked. The following information was recorded for each captured individual: date, locality in the marsh, sex, length, and age when possible. An indication of seasonal activity of turtles was obtained by trap records and field observations. Growth rates were determined by age-length relationships and by recaptures.

Reproductive cycles and reproductive potential were determined by dissection of 293 turtles from a population in a lake located two miles from the marsh. The two habitats are not connected by water.

The male reproductive cycle is divisible into three phases. From late March to early May (the mating season) the testes are small but the sperm ducts are filled with sperm. Spermatogenesis occurs from July to October. This results in an increase in testis size. The winter phase is characterized by small testes. Most of the sperm are contained in the epididymis at this time. Transitional periods occur between each of these phases. Courtship behavior occurs in spring and fall, but effective mating probably does not occur in the fall.

Ovarian follicles begin to increase in size in September. By March the largest follicles are around 16mm in diameter. Immediately before ovulation these increase to about 18mm in diameter. Ovulation occurs around the middle of May and enlarged follicles, as well as the oviducal eggs, are invariably present at this time. Presumably a second clutch is laid. The second ovulation probably occurs in middle June. Mean clutch size is about 6.5 eggs and the annual reproductive potential for an individual is around 13 eggs.

Growth rates in the marsh population are similar throughout the juvenile years but decrease abruptly in both sexes when maturity is reached. Growth rate apparently decreases to some degree as mature turtles grow older.

The survivorship pattern, based on the study populations, is a combination of a Type IV curve (egg-juvenile) and a Type III (adult). The former is characterized by high mortality in the egg stage (98 percent) followed by low mortality of the juveniles. Once maturity is reached by either sex, mortality is constant.

Adults become active in early spring when water temperatures reach the minimum tolerance limits. Reproduction is believed to be the incentive for this early activity. Distances traveled by mature males are greatest in the spring.

By late May most Chrysemys become associated with areas of aquatic vegetation. Travel within the marsh is limited throughout the summer. Juveniles and mature males are found in the same general area in successive summers whereas mature females have often traveled long distances. This is attributed to females leaving the water in one area for nesting purposes and returning to the water in another area.

By September the turtles begin to leave summer feeding areas which are unsuitable for winter. Activity at low temperatures is reduced in the fall.

POPULATION DYNAMICS AND ECOLOGY OF THE PAINTED TURTLE, CHRYSEMYS PICTA

By

J. Whitfield Gibbons

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INTRODUCTION

Cagle (1953) points out that most ecological studies on reptile populations have not met the "critical standards" necessary for formulating ecological principles and advancing ideas. He further indicates that the numerous facts concerned with reptile ecology are of such a diverse nature that they can seldom be satisfactorily integrated. The same is true today, particularly in regard to freshwater turtles.

Thorough natural history studies have been made on a few species of North American turtles, namely *Sternothaerus odoratus* (Risley 1933), *Gopherus agassizi* (Woodbury and Hardy 1948), *Pseudemys scripta* (Cagle 1950; Webb 1961), *Terrapene ornata* (Legler 1960), and *Graptemys pseudogeographica* (Webb 1961).

Several authors (Cahn 1937; Pope 1939; Breckenridge 1944; Conant 1951; Carr 1952; Smith 1961) have included brief accounts of the natural history of *Chrysemys picta* in general treatises of turtles. These accounts provide little quantitative information regarding the ecology and life history of the species. Because of its widespread distribution and abundance, however, *Chrysemys picta* has been the subject of a number of studies involving particular aspects of its natural history.

Pearse, Lepkovsky, and Hintze (1925), Raney and Lachner (1942), Marchand (1942), and Lagler (1943) investigated the food habits of Chrysemys. The general consensus was that the species is omnivorous. Pearse (op. cit.) and his cohorts also reared laboratory individuals on various diets and concluded that growth was influenced by the vitamin content of the foods eaten.

Studies on home range and migration in turtles have been particularly popular. Such studies on Chrysemys (Pearse 1923a; Cagle 1944a; Williams 1952; Sexton 1959a) have formulated a general picture that this species confines its activity to a restricted area if conditions are suitable but will travel great distances if such conditions do not exist. Sexton (1959a) investigated the environmental factors influencing movement and determined the seasonal activity cycle of the species. The presence of surface vegetation has been hypothesized as being the important factor in determining the suitability of an aquatic area (Meseth and Sexton 1963). Ortleb and Sexton (1964) experimented with several factors which might be important in Chrysemys orientation.

Limited information has been collected concerning growth rates by Pearse (1923b) and Cagle (1954) who point out that juveniles grow much faster than adults. The growing season of Chrysemys in southern Michigan was defined by Sexton (1965) as being June 1 to August 31.

Cagle (1954) gives an account of the life cycle of Chrysemys by consolidating the previous literature and supplementing this with personal observations. He states that there is a need for more information concerning natality, mortality, attainment of maturity, and population densities of turtles.

The remainder of the information on the natural history of Chrysemys picta is to be found in short reports of casual observations. A systematic investigation of the life history and ecology of the species has not been previously accomplished.

In recent years, increased interest in population ecology has placed an emphasis upon studies of natural populations of animals. Numerous animal species have been investigated in attempts to analyze their population dynamics and to relate these changes to the ecology of the species. A successful analysis of population dynamics, however, is dependent upon the qualities of the species studied. Emigration and immigration often change the complexion of the population. Ages of individuals are often difficult to determine. Dead animals are seldom found, so that few clues are given as to the causes of mortality in most species. Also, the investigator himself often becomes a major environmental factor.

Chrysemys picta has many attributes which make it a favorable study species in investigations of the dynamics of natural populations. *Chrysemys* are usually found in distinct, well defined populations. Aging is possible to a much greater extent than is true of most other animals and size can be accurately defined by measuring plastron lengths. Information on mortality can be gained because of the durability of turtle shells after death of the individual. *Chrysemys* can be permanently marked for individual identification without injuring the animals or distrubing the population. The sexes can be distinguished externally.

The two objectives of the present study were (1) to investigate the natural history of the painted turtle, *Chrysemys picta*, and (2) to analyze the population dynamics of a natural population of animals.

The study quantitatively analyzes the life cycle and population dynamics of *Chrysemys picta* in southwestern Michigan, and provides descriptive information concerning the ecology of the species. Reproductive cycle and reproductive potential were determined for the turtles from one population. Individual growth rates, population structure, seasonal activity, and environmental conditions were determined for another population. Integration of data from these two sources results in a quantitative and descriptive life history of *Chrysemys picta*.

MATERIALS AND METHODS

The Study Species

Chrysemys is a genus of New World, aquatic, emydine turtles generally considered to contain a single species, *Chrysemys picta*. The genera *Pseudemys* and *Trachemys* are regarded as being most closely related to *Chrysemys* (Carr 1952), and have been included as subgenera of *Chrysemys* (McDowell 1964). *Chrysemys picta* is composed of four recognized subspecies. The present study was conducted within the range of *C. p. marginata* Agassiz.

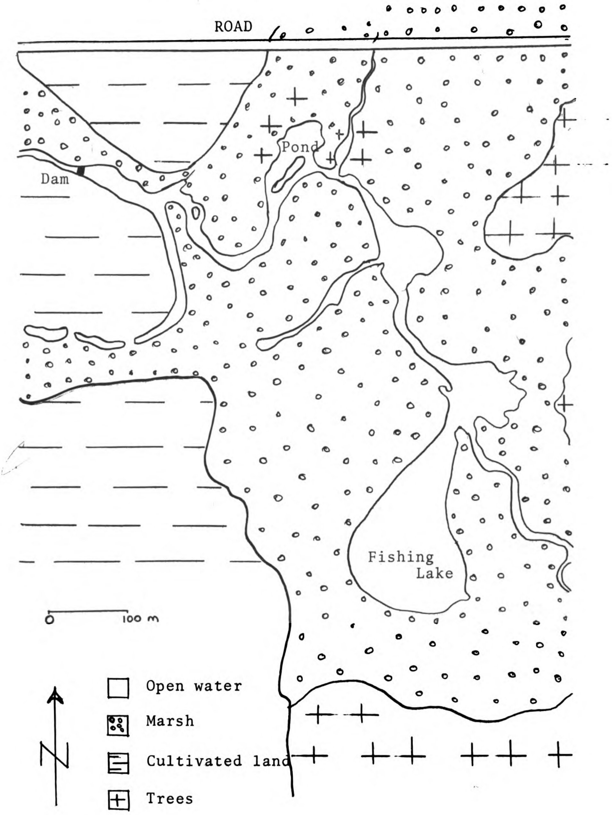
Description of the Study Areas

The major portion of the study was conducted at two localities, Sherriff's Marsh and Wintergreen Lake, in Kalamazoo County, Michigan. In addition, observations were made on a few turtles from the Kalamazoo River in Allegan County.

Sherriff's Marsh

Sherriff's Marsh (Figure 1) is located in the northwest corner of Kalamazoo County, Michigan, in Sections 2, 3, and 11, T1S, R9W. The marsh is comprised of more than 75 acres of a grass-sedge association and approximately 14 acres of open water.

Figure 1. Sherriff's Marsh



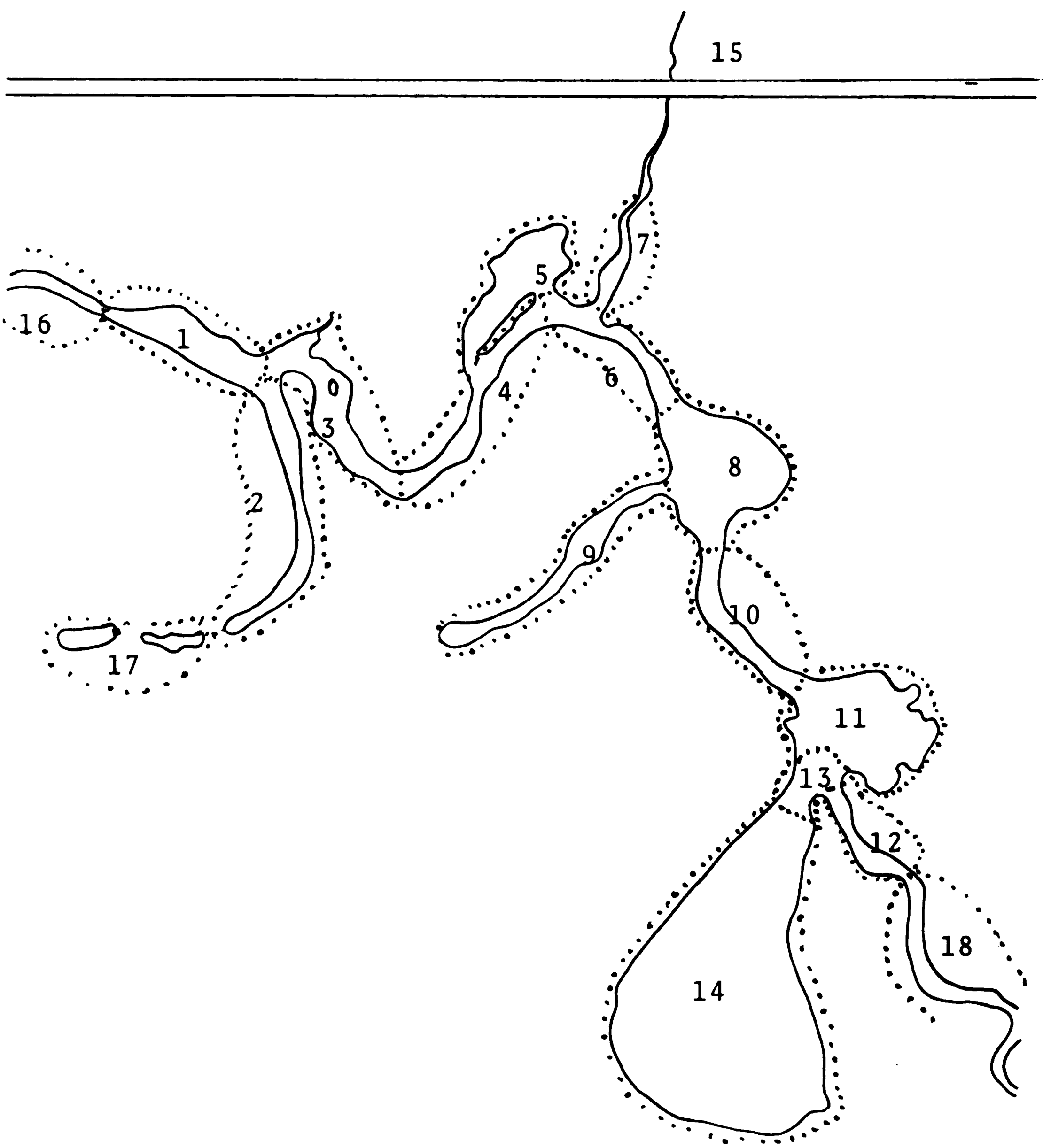
The primary water source is Hamilton Lake, a hard-water lake located one mile to the east. A fast-flowing stream from Hamilton Lake enters the southeast corner of the marsh, whereupon it widens and becomes a winding, slow-moving channel. The channel narrows again at the northwest corner of the marsh where it connects with Augusta Creek. A small dam was constructed across the channel in the northwest corner in the early 1930's. This raised the water level several centimeters throughout the marsh and resulted in the death of a stand of tamarack along the eastern border.

The vast majority of the marsh consists of grasses and sedges growing in soggy, often flooded areas away from the main channel. The roots of the plants form a dense mat. The open water in the marsh consists of approximately a mile of winding channel and its extensions, a 5-1/2 acre lake, a one acre "pond," and the entrance of a small stream from the north. All of these bodies of water are interconnected.

The open water areas were divided into 15 zones to facilitate reference to particular locations in the marsh (Figure 2). With the exception of Zones 3, 4, and 6 in which the places for division were arbitrarily picked, all zones represent habitats which are distinct from the adjoining zones. The area north of the marsh was also designated as a zone (15).

The main channel varies from 10 to 20 meters in width. The bottom is silt and not solid in most areas.

Figure 2.--Zoning system at Sherriff's Marsh



The water depth was measured from the top of the silt layer to the surface of the water and ranged from one to two meters in depth in the main channel through the marsh.

At two places the channel widens into larger bodies of water (Zones 8 and 11) which are 80 and 100 meters at their widest diameters. Zones 2 and 9 are side extensions of the main channel and are similar to it in most respects except for being narrower (6-8 meters) and shallower (1/2 to 1 meter). Surface vegetation in the form of Lemna and Spirodela is much more prevalent in these side channels than in the main channel.

Aquatic vegetation is similar in all parts of the main channel. Coontail (Ceratophyllum demersum) is the dominant submergent. This species reaches such a density that by midsummer it occupies most of the aquatic habitats in the marsh. Clumps of Chara sp. occur occasionally, but Ceratophyllum demersum is by far the most abundant aquatic plant. Duckweeds (Spirodela polyrhiza and Lemna minor) form a surface mat in many places, particularly along the shore. Water lilies (Nymphaea odorata and Nuphar advena) are abundant. The most common emergents are cattails (Typha latifolia), swamp loosestrife (Decodon verticillatus), arrow arum (Peltandra virginica), bulrushes (Scirpus validus), and arrowhead (Sagittaria latifolia). Several species of sedges (Carex) and grasses (Gramineae), the most common being Calamagrostis canadensis, occur along the margins.

The pond (Zone 5), although connected directly with the main channel, is vegetatively distinctive. Marginal vegetation is similar to that in the rest of the marsh. Ceratophyllum demersum is the dominant submergent, but does not reach the density of that in the channel. The apparent reason for this is that Spirodela and water meal (Wolffia punctata) cover almost 100 percent of the water surface by July, thus preventing underwater plants from receiving adequate light. Presumably the pond's unbroken layer of Spirodela and Wolffia results from the wind protection afforded by clumps of trees to the north and east and by a row of bushes along the small stream to the west. The length of the pond is 110 meters; the width varies from 15 to 50 meters. The depth is less than one meter. The bottom, in contrast to the rest of the marsh, is relatively solid.

The stream entrance (Zone 7) is only a small area of the marsh but should be mentioned because of its physical and vegetational differences from the main channel. Near the road the stream is less than 30 centimeters deep and one meter wide. The area where it enters the channel is still water, 10-30 centimeters in depth, and often a few degrees colder than the main channel in the summer. Spirodela covers up to 50 percent of the surface in the summer. A large Chara bed occupies the northwest corner. Ceratophyllum is present in insignificant amounts. The stream entrance is margined by two parallel ridges of dirt, each about one meter high. Red osier dogwoods (Cornus stolonifera) and swamp roses (Rosa palustris) are common on these ridges.

Fishing Lake (Zone 14) is notably different from the remainder of the marsh. Its larger size and greater depth (up to four meters) precludes the density of vegetation characteristic of the main channel. Most of the aquatic vegetation, primarily Ceratophyllum and bladderworts (Utricularia vulgaris), is restricted to the marginal 15 meters. The middle portion of the lake is devoid of plants. The short channel connecting Fishing Lake and the main channel is completely filled with lily pads during the summer.

Wintergreen Lake

Wintergreen Lake (Figure 3), on the W. K. Kellogg Biological Station of Michigan State University, is located in Section 8, T1S, R9W, Kalamazoo County, Michigan. The lake is two miles southwest of the western edge of Sherriff's Marsh. The two habitats are not connected by water (Figure 4).

Wintergreen Lake is highly eutrophic with organic bottom sediments. Nymphaea odorata and Nuphar advena are common around the margins. Ceratophyllum demersum and pondweeds (Potamogeton pectinatus) are the dominant submergents but do not attain the density that is found in the

Figure 3.--Wintergreen Lake

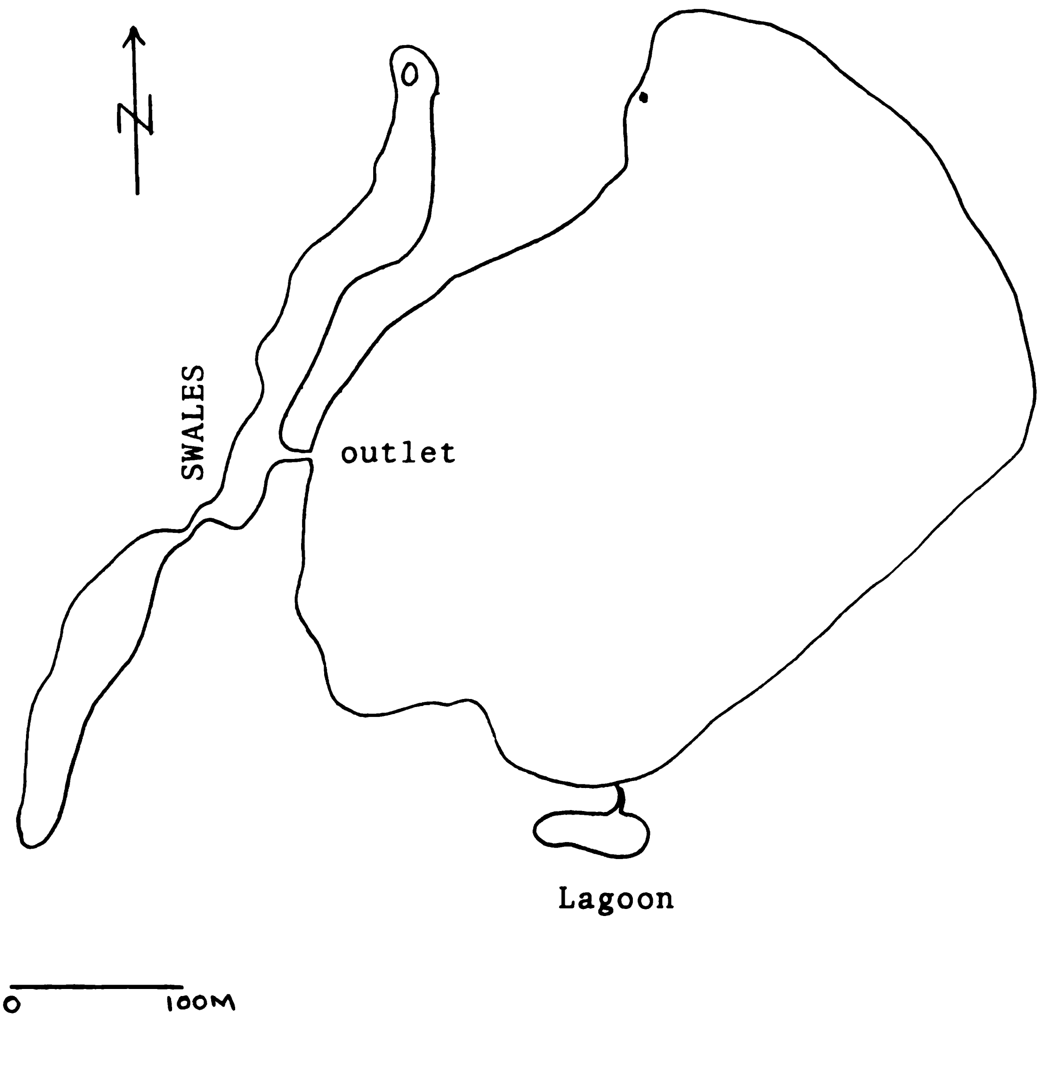
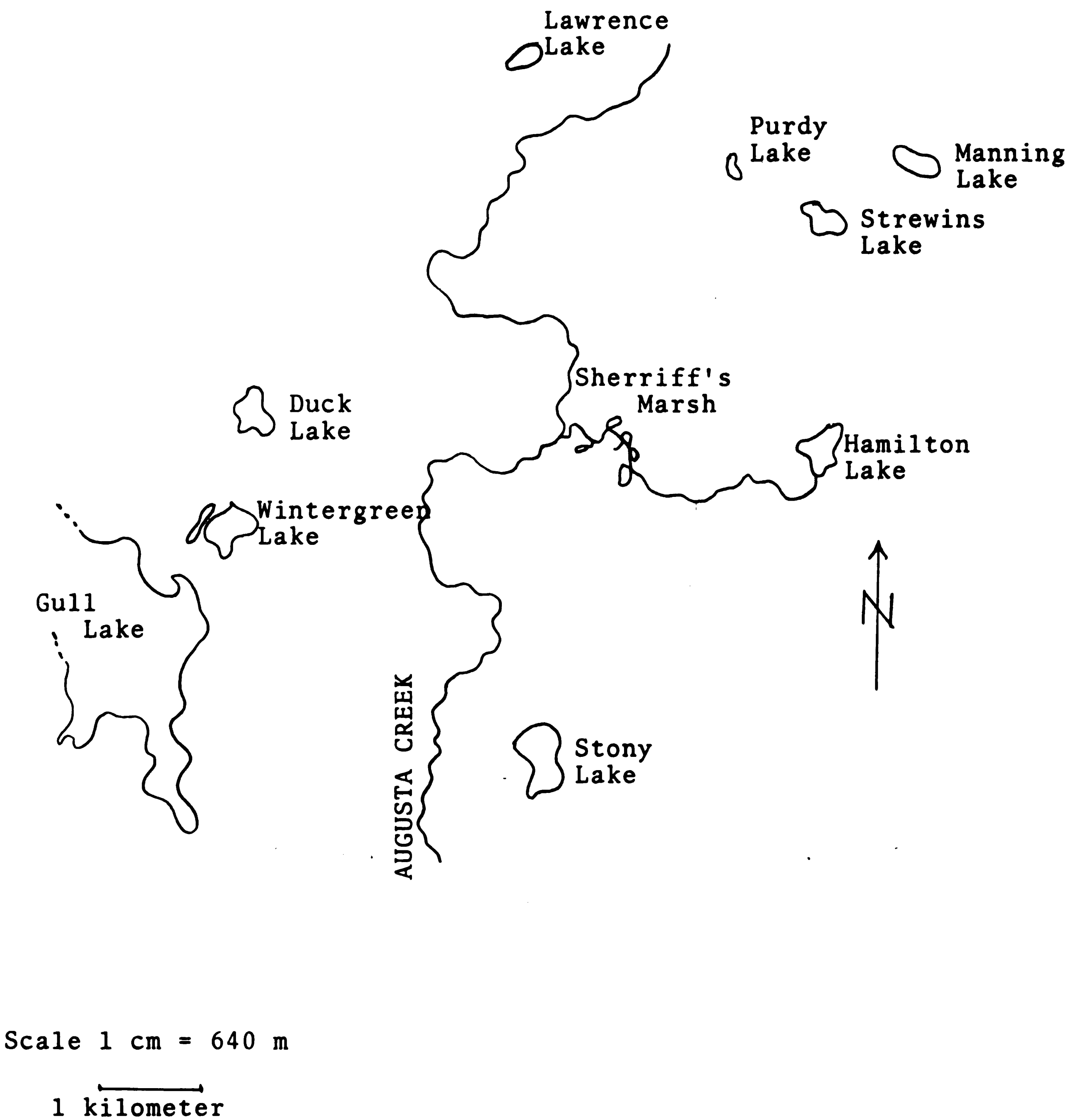


Figure 4.--Map showing relationship between Wintergreen Lake and Sherriff's Marsh in northeastern corner of Kalamazoo County, Michigan.



marsh. The lake proper is approximately 20 acres in extent with a maximum depth of slightly less than seven meters.

A narrow channel on the western edge connects the lake with several elongate swales which were cleared in 1961 to provide nesting areas for geese. These swales, though containing water throughout the year, are seldom more than a meter in depth.

On the southeastern edge of the lake and connected directly with it by two narrow channels is an 80 x 30 meter "lagoon." The depth is 1-2 meters. Although fences in the channels and on the land around the lagoon isolate it from the rest of the lake, limited interchange between the lake and lagoon turtles occurs overland through broken areas in the fence.

Kalamazoo River

A few of the *Chrysemys* used in the study were taken from a polluted stretch of the Kalamazoo River in Section 21, T1N, R12W, Allegan County, Michigan. Most of the turtles were collected from a shallow mud flat in an area of sparse aquatic vegetation. The river in this area is polluted by industrial and domestic wastes from the city of Kalamazoo only 15 miles upstream.

Water Temperature and Depth

Water temperature at the marsh was taken with a hand thermometer at the start of each collecting trip. The temperature was always taken at the same spot in the channel at a depth of 30 centimeters. On occasion readings were made at other locations in the marsh and at several depths for comparative purposes. Water depth was determined on each collecting day by reading a meter stick placed in the water near the dock area.

Collecting Methods

Twelve techniques were used in capturing turtles from Sherriff's Marsh and Wintergreen Lake. The relative merits for each of these will be discussed separately.

Hand or Dip Net

The most successful collecting method throughout the study was simply looking for turtles in the water and then catching them either by hand or by the use of a dip net. A wooden-handled net with 1/2 inch mesh near the rim grading into 1/4 inch mesh at the tip was found to be suitable for capturing turtles of all sizes. At Wintergreen Lake most of the turtles collected by this method were in the water along the edge of a walkway. In the marsh, the majority of the collecting was done from a rowboat. More than 1000 of the turtles collected during the study were captured by this technique.

Swim-in Traps

Traps constructed of three-inch wire mesh also were successful in collecting turtles. The body of the trap consisted of a three-foot diameter, five-foot high cylinder standing on end. The bottom was of wire mesh but the top was open. A one-foot square was cut out of the cylinder about six inches from the bottom. The square was bordered by wire mesh extending six inches into the trap. Traps were placed along shore in shallow water. Accompanying each trap was a wire drift fence six feet long and two feet high. One end was placed at the side of the door away from shore, and the fence extended away at a 45° angle to the shore. The result was a funnel formed by the shore and the fence. Turtles traveling parallel to shore entered the trap through the open door. Thirteen of these traps were used in the marsh. Most were never moved from their original locations. The traps have the advantage of not requiring any maintenance, such as baiting, yet they are always operative. Since the top is open, there is no chance of a turtle drowning should the trap not be checked at regular intervals. The major disadvantage of these traps is that they are restricted to use in shallow water near shore, and also, the use of three-inch mesh undoubtedly allows smaller turtles to escape.

Bait Traps

Several bait traps, constructed of 1/2 inch mesh galvanized hardware cloth, were used at the marsh. The traps were two feet long and one foot square with funnels at each end. Sash cord was tied at the top so that the trap could be lowered to any depth and the cord tied to some object along shore. Dead fish or chicken necks, placed in a hardware cloth bait container, served as bait.

Basking Traps

A trap of this type was used to a limited extent at Wintergreen Lake. The trap consisted of a three-foot square wire mesh basket with attached floats. A short wooden plank was connected to each side in such a way that it extended about a foot into the water on the outside of the basket. The other end of each plank was elevated slightly over the inside of the basket. Turtles crawling onto the plank to bask would often enter the water off the elevated end and become trapped in the basket.

Underwater Diving

This technique used at the marsh was extremely successful under certain conditions. A rubber dry suit, fins, an underwater face mask, and a snorkel (or SCUBA) were used during certain times of the year for capturing turtles. By this method the investigator could swim along until a turtle was seen. The fins enabled one to swim faster than most *Chrysemys*. This technique was used to best advantage in the spring and fall when the water was clear and vegetation at a minimum. It was also found to be an excellent method of approaching basking turtles and catching them before they entered the water.

Terrestrial Traps

In an attempt to capture females during the egg laying period a terrestrial drift fence was used. A funnel composed of two eight-inch-high fences of hardware cloth each about 30 feet long extended from the water's edge onto land at a 45° angle. At the apex a space of 6-8 inches between the two fences led into a circular, fenced-in area about three feet in diameter. The opening was bordered by hardware cloth extending six inches into the enclosed area. Female turtles leaving the water to lay eggs were funneled into the circular area. These traps proved to be valuable in providing information concerning nesting.

Hatchling Traps

A drift fence was used to determine when hatchlings leave the nest in the spring. Fences were 100 feet long and constructed of eight-inch-high hardware cloth placed parallel to the shoreline. Two-pound coffee cans with the open end level with the surface were embedded in the ground beneath the fences at 20-foot intervals. Hatchlings encountering a fence would follow it until they fell into one of the cans. This technique proved successful for the purpose for which it was designed.

Muddling

This technique, employed by most turtle investigators at one time or another, consists of feeling by hand through mucky areas until a turtle is found. In the present study, the greatest success was attained in November of 1965 in Wintergreen Lake. Attempts at muddling in the marsh were seldom rewarding.

Seining

A 20-foot seine was used on one occasion at Wintergreen Lake. Since only three turtles were caught in several hauls, and since operation of a seine requires two people, this technique was not employed during the remainder of the study.

Shooting

A pellet gun was used on one occasion in an attempt to shoot basking turtles at Wintergreen Lake. Usually, when one got close enough to shoot, he was also close enough to run into the shallow water and catch the turtle with a dip net. There also is the disadvantage that specimens might be damaged when hit with the pellet.

Road Collecting

Many turtles were picked up during the spring and fall on highways in the area or on the roads bordering Wintergreen Lake. Although many specimens were obtained in this manner, the chances of finding turtles on any given day made planned terrestrial collecting unprofitable.

Lures

Near the completion of the study it was discovered that some *Chrysemys* would follow a fishing lure being pulled over the top of thick aquatic vegetation. Several individuals actually followed the lure up to the boat and were captured. Whether this technique could be used for extensive collecting was not determined.

Marking, Measuring, and Aging

Turtles in Sherriff's Marsh were marked for individual identification and usually released a few minutes after capture. Notching the marginal scutes with a small rectangular file was found to be the most efficient method of marking adult *Chrysemys*. Cutting v-shaped notches with fingernail clippers was most effective on the flexible shell of juveniles. Though marked marginals occasionally bled, no permanent damage was known to occur as a result of marking. The notches on turtles marked in 1964 and recaptured in 1966 were not noticeably different from notches on turtles that had been marked for less than a month. It was not necessary, therefore, to remark individuals and it is assumed that all previously marked turtles were recognized as such when they were recaptured.

As an aid to determining the distance traveled by marked individuals without making a capture each time, letters of the alphabet were painted down the center of the carapace with white enamel. In this way the letters on basking or swimming individuals could be read without having to capture the turtle. This method was very effective in early spring. With the onset of dense vegetation, little open water was present in which to see swimming turtles and those basking often had carapacial algae which obscured the letters. This method of marking was not permanent, since *Chrysemys* shed their scutes annually.

Plastron length was used as a measure of size and was taken to the nearest millimeter with a plastic ruler. Age was determined by the number of annuli present on the left pectoral plate. Estimates of age in older individuals using the method given by Sexton (1959b) were not made, because variability in the length of annuli was too great. All ages given in this study, therefore, are based on the actual number of annuli.

Head Counts

The number of *Chrysemys* heads at the surface were counted in selected areas of Sherriff's Marsh during 1965. The boat was stopped 30-40 meters from the area to be observed, and the heads counted by using binoculars. Each area was 54 square meters. A record was kept of the surface vegetation present in the area at the time of each observation.

Determination of Reproductive Cycles

The study specimens were usually dissected within 24 hours after their capture. The testes were removed, blotted with paper towels, and weighed to the nearest one hundreth gram on an Ohaus Triple Beam Balance. Follicles were measured individually at the widest diameter with Vernier calipers. The average diameter of follicles in the largest set was determined only if a distinct size class was apparent.

The anatomical criterion for maturity in males was the presence of testes weighing more than 0.01 g. The criterion utilized for ascertaining female maturity was the presence of follicles greater than 10mm in diameter (Cagle 1954).

Long foreclaws is a good indicator of maturity in male *Pseudemys scripta* (Cagle 1948). In the present study, 86 *Chrysemys* males were examined internally and all mature individuals possessed long claws (third claw greater than 10mm in length). With one exception, all immature males had short claws (third claw less than 9mm in length). The presence of elongated front claws was therefore considered to be dependable enough to be used as a criterion for determining maturity in males from Sherriff's Marsh.

Growing Season

Sexton (1965) considered that most of the growth in *Chrysemys* from southeastern Michigan occurred from June through August. Mark-recapture results during the present study have shown that at least some growth occurs during May and September. Individuals from the study populations are considered as having one growing season (May through September) per year.

Nesting Experiments

Twelve mature females, collected in the spring of 1966, were used in controlled nesting experiments. Seven of these were kept in outdoor pens which were placed in an area with soil type similar to that in which local *Chrysemys* often dig their nests. The five remaining females were kept indoors in large aquaria containing sand to a depth of seven centimeters.

Determination of Population Size

The Lincoln Index (Allee *et al.*, 1949) was used to estimate the number of individuals in the different age, sex, and size classes. The following formula was used.

$$\frac{\text{Number of individuals which were already marked at the beginning of the collecting period} \times \text{Number of individuals (marked and unmarked) which were captured during the collecting period}}{\text{Number of marked individuals captured during the collecting period}}$$

Each size-sex category was estimated separately. The final estimate for each category was derived by taking the average of the estimates for six collecting periods. Estimates obtained by this method may be subject to error for a number of reasons. The possible sources of error in estimating the size of the present population are listed and evaluated as follows.

Natality

New turtles were added to the population in the spring of 1965 and 1966. Hatchlings of 1965 were treated as part of the juvenile population in deriving an estimate. Hatchlings of 1966 were not included in making an estimate of the juvenile population. The reason for this is that all estimates prior to the summer of 1966 were based only on the turtles which were in the population at the start of the summer of 1965. Including the 1966 hatchlings which appeared in the final collecting period would have led to an underestimation of the total juvenile population in 1966.

Selection Against Marked Animals

No marked turtles in the present study were known to be harmed or disabled by being marked. The methods of marking, therefore, are assumed to have had no influence on an individual's chances of remaining in the population.

Growth During the Study

A few turtles passed from immature to adult categories during the census period. Such individuals were classed in their original category for purposes of estimating population size. This caused a small degree of overestimation in the juvenile category and underestimation in the adult categories. The effect on final estimates was negligible.

Mortality

Death of turtles during the study is assumed to have had little effect on estimation of numbers. Death is not a factor of error in estimating numbers for any given collecting period, since marked and unmarked turtles have equal opportunities to die.

Migration

Migration of turtles to or away from Sherriff's Marsh was probably minimal and had little effect on estimation of population size. Some interchange undoubtedly occurred between turtles in the study area and those in Zones 16, 17, and 18 in which no collecting was done. Movement of turtles between these zones and the study area would result in an overestimation of the population size.

Behavior of Marked Turtles

A possible source of bias was that marked animals may be less likely to be captured than unmarked animals. Evidence that some *Graptemys* and *Pseudemys* become more wary after being captured and released is presented by Tinkle (1958). Sexton (1959a) found that unmarked *Chrysemys* often allowed the collector to get closer in a boat than did previously marked individuals. Behavior of this type was not observed in the present study, but if it did occur, an overestimation of population size would result.

Random Redistribution

One of the assumptions in using the Lincoln Index is that a previously marked individual has as much chance of being collected as any other individual in the population. This assumption cannot be met in a natural population of animals. Although turtles were collected throughout the prescribed study area, certain areas were collected more extensively than others. Hence, a greater proportion of turtles were marked in some zones than in others. However, during each of the six collecting periods on which the estimation was based, some amount of collecting was done in each part of the marsh. The error caused by non-random redistribution was therefore minimized.

Inherent Error

The Lincoln Index is based on chance. Even if it were possible to sample completely at random, the estimation of population size would probably still be aberrant from the true population size. Each estimate therefore must be considered as a general assessment of population size, not as a calculated number of individuals. Nevertheless, a knowledge of the approximate size of the population is useful and imperative when dealing with the dynamics of an animal community.

RESULTS

Physical Parameters

Fluctuations in water level at Sherriff's Marsh from March 1965 to November 1966 are shown in Figure 5. A rise in water level began in August 1965 and continued into March 1966. The lowest level for each year was reached in July but was 33 cm higher in 1966.

Water temperatures varied between 1965 and 1966 (Figure 6). Thawing was earlier in 1966, occurring in the middle of March, whereas in 1965 the ice did not begin melting until the first week in April. Temperatures remained several degrees higher in 1966 than in 1965 until the first week in April when a cold spell sent water temperatures near the freezing mark. During the last half of April, temperatures were similar for both years. Water temperatures taken in the first half of May were consistently higher in 1965 than in 1966. The incongruity of the dates on which readings were taken in late May and early June makes comparison of the two years difficult. However, temperatures averaged in the low 20's during this period in both years.

Water temperatures were relatively constant during June, July, and August but were generally 3-4° C higher in

Figure 5.-- Monthly averages of water level changes at Sherriff's Marsh from March 1965 to November 1966.

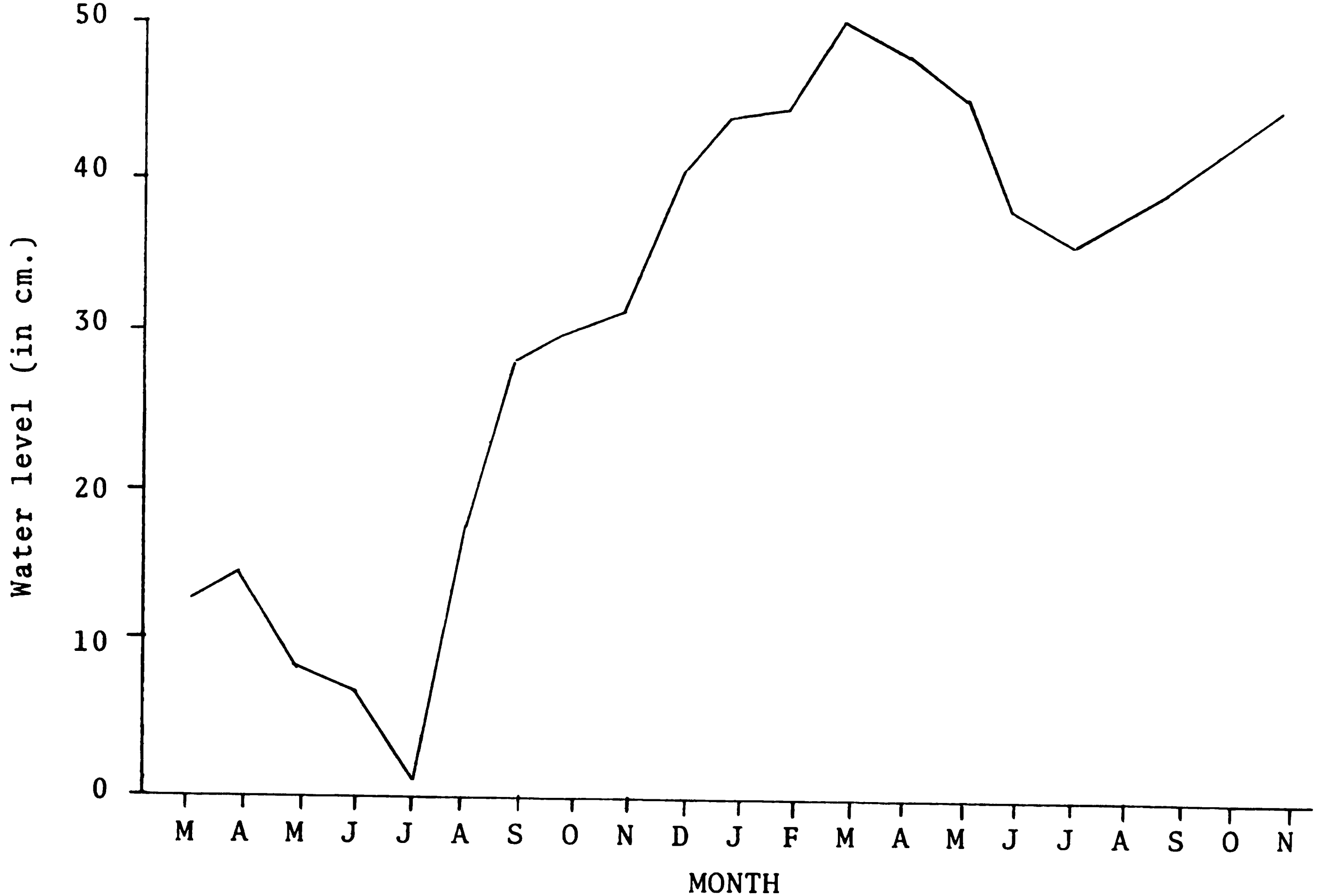
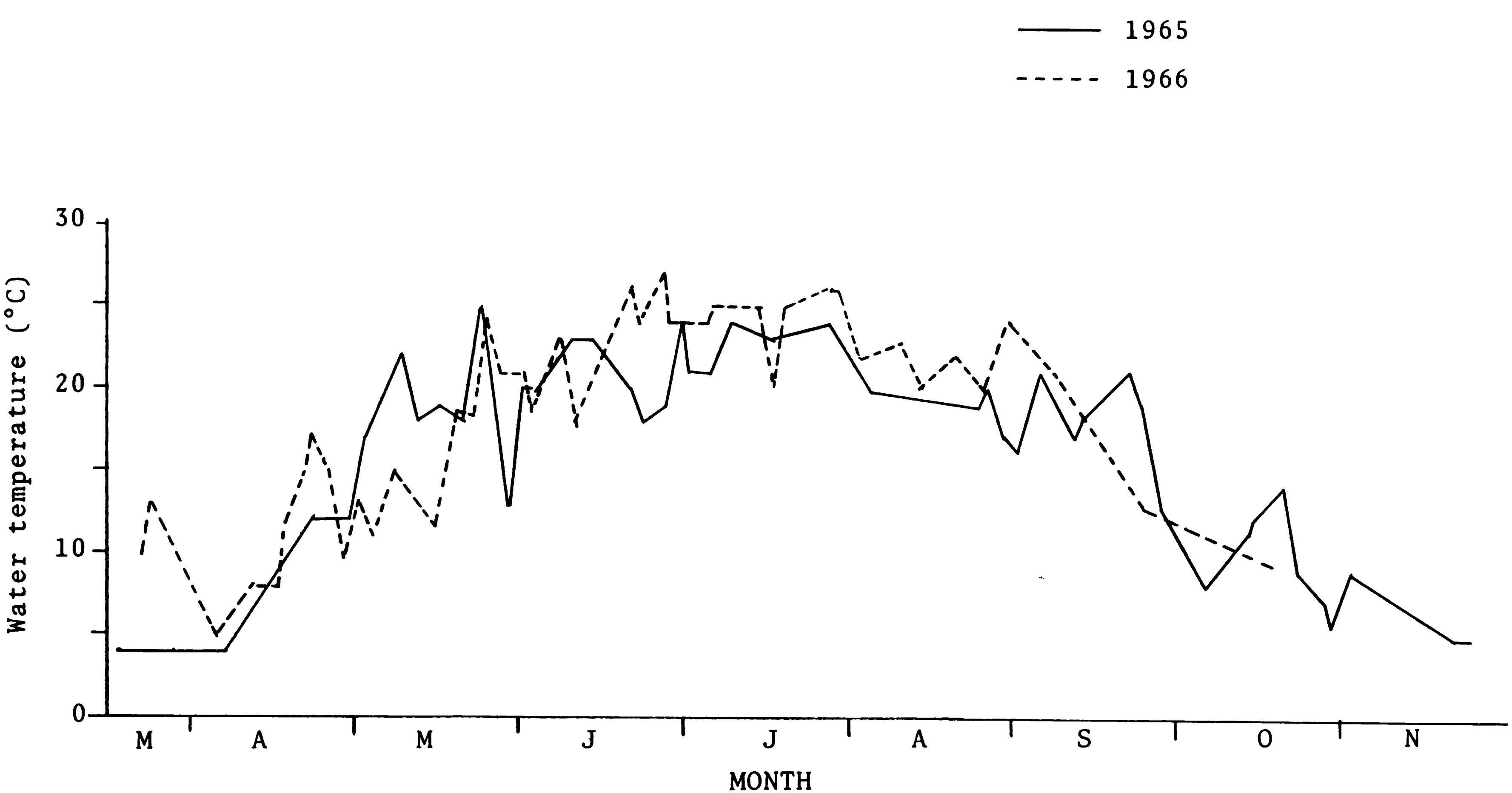


Figure 6.--Water temperature at a depth of 30 cm in main channel of Zone 3 at Sherriff's Marsh.



1966. Temperatures dropped considerably in late September of 1965. Readings were taken on too few dates in the fall of 1966 to compare with 1965, though presumably water temperatures followed a similar trend. Most of the marsh was frozen by late December of both years.

Reproduction

Size and Age at Maturity

Eighty-two *Chrysemys picta* males from Wintergreen Lake and four from the Kalamazoo River were dissected and examined for purposes of determining the annual reproductive cycle and the size or age at which maturity is attained. All *Chrysemys* males with a plastron length exceeding 81 mm were mature (weight of testes > 0.01g). Two specimens measuring 75 mm and one with a plastron length of 79 mm proved to be immature.

Since mature males can be distinguished by the possession of long claws, this secondary sex characteristic, rather than dissection, can be used to indicate the size at which maturity is reached in a population. Table 1 gives the percentage of turtles between 70 and 85 mm recorded as mature males in the marsh population. Since, assuming a 1:1 sex ratio, half of the animals would be expected to be males, the paucity of those below 80 mm recorded as males is presumably a result of there being few mature individuals.

Table 1.--Relationship between maturity (based on long fore-claws) and plastron lengths of *Chrysemys picta* males from Sherriff's Marsh in 1966.

Sample Size	Plastron Length (mm)	% Recorded as Males on basis of foreclaw length
5	70	0
7	71	29
9	72	0
2	73	0
8	74	0
3	75	0
5	76	0
10	77	20
7	78	14
3	79	0
7	80	29
8	81	63
3	82	67
7	83	57
9	84	56
8	85	88

Regression equations were determined for the growth of immature individuals from the lake and marsh populations. The 95 percent confidence interval for the regression coefficient of the lake population is 3.55 ± 0.69; that for the marsh population is 1.96 ± 0.15. The growth rate is approximately 18 to 26 mm per year for the lake turtles and 9 to 10 mm per year for those from the marsh. Since hatchlings are usually close to 25 mm in plastron length, males from the lake attain a length of 80 mm in their third to fifth year, whereas males from the marsh are in their sixth or seventh year.

A total of 207 female Chrysemys picta from Wintergreen Lake was dissected to determine the reproductive cycle and the size at which maturity is attained. As with the males a comparison was made between females from Wintergreen Lake and those from Sherriff's Marsh to establish if reproductive maturity was dependent upon size and not age.

Four females 118 to 125 mm in plastron length from the marsh had oviducal eggs present as determined by palpation during June 1-7, 1966. Seven females which were not carrying eggs were 90 to 100 mm in length and seven to 12 years old. Although no large samples of Chrysemys were removed from the marsh population, two females were dissected in August 1966. These were 103 and 106 mm in plastron length and nine and 11 years old. Both had immature ovaries. Six mature females from Wintergreen Lake ranging in size from 116 to 125 mm were seven to 10 years old.

All dissected females with plastron lengths of at least 117 mm were mature (follicles > 10 mm in diameter) or showed signs of follicular enlargement (Figure 7). All specimens below 112 mm in plastron length showed no development of the ovaries. Four individuals (44 percent) of nine ranging from 111 to 115 mm and three (15 percent) of 20 from 116 to 120 mm were considered immature. Of 26 females with plastrons measuring 121 to 125 mm, only one individual (4 percent) was not mature.

Seasonal Changes in Males

Testis size and development are dependent upon size of the turtle and season of the year (Figure 8). At least two seasonal phases of testicular development were evident. In the spring phase (March-June) testes were reduced in size though the sperm ducts were often enlarged, thickened, and heavily packed with sperm. In the summer phase (July-September), testes were greatly enlarged but sperm ducts were small and lacked sperm. Three specimens collected in October tended to have testes similar in size to those of the spring phase, whereas testes of three specimens examined during the last week in June approached more closely the summer phase. Three individuals dissected during the first week in January had testes with weights corresponding to the spring phase. The sperm at this time were contained primarily in the epididymis.

Enlargement of the sperm ducts was most prevalent in April. Fifteen, of 16 males dissected, had the vasa deferentia filled with sperm. During the first half of May

Figure 7.--Relationship between plastron length and maturity of female *Chrysemys picta*

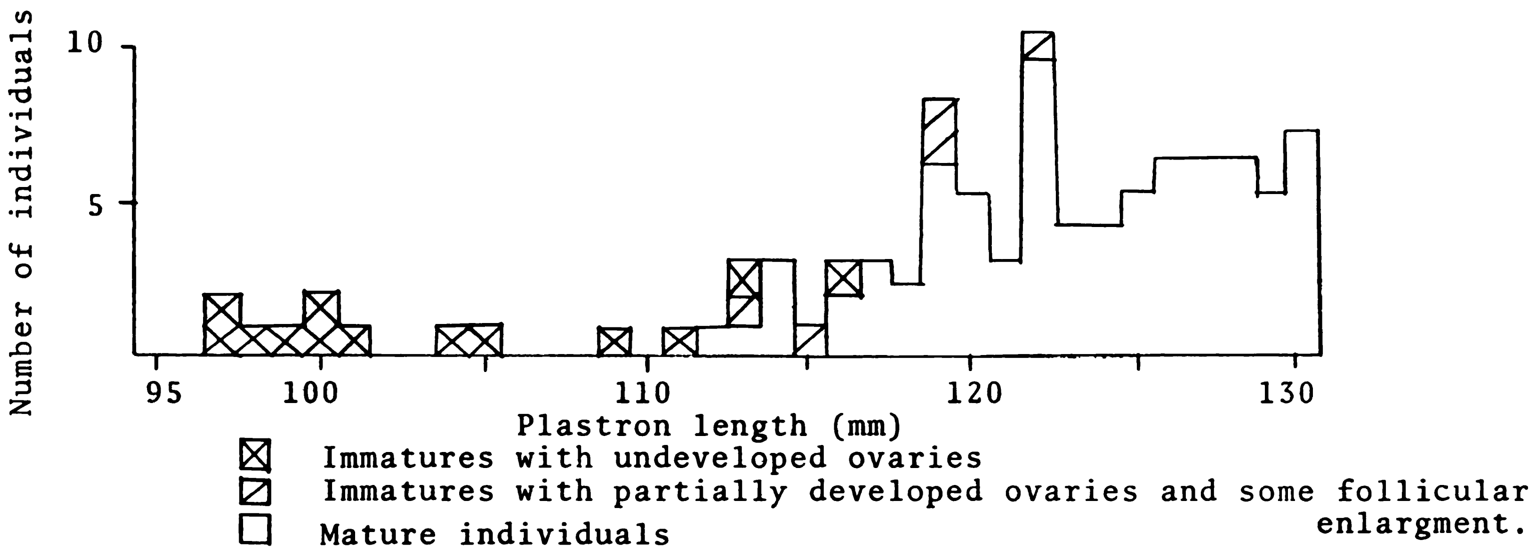
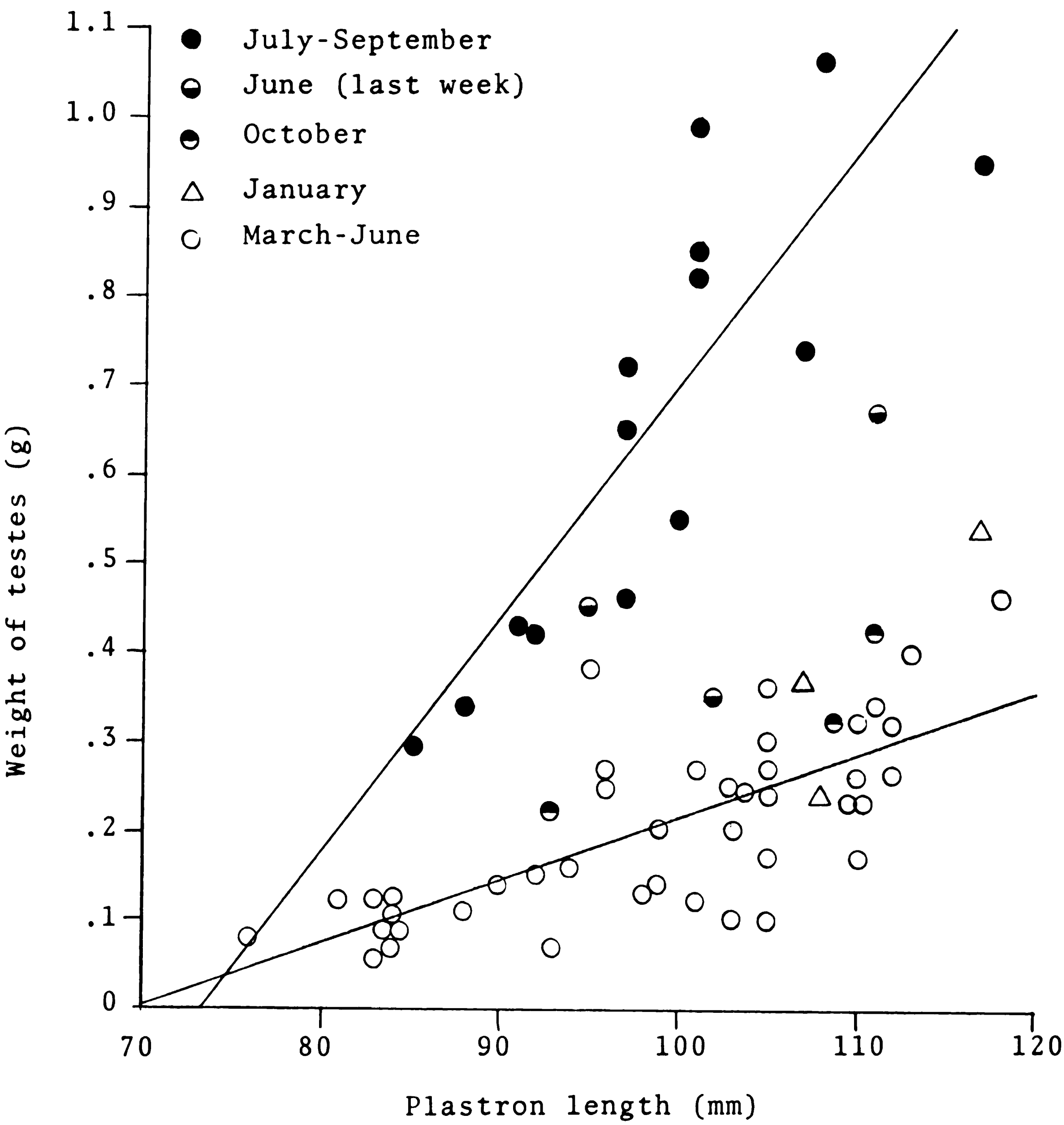


Figure 8.--Relationship between plastron length and weight of the testes of *Chrysemys picta* from Wintergreen Lake. Regression equation for July-September is $y = -185.2 + 2.55X$. Regression equation for March-June is $y = -48.2 + .69X$.



only three out of nine animals had enlarged ducts. All individuals had small vasa deferentia during the latter half of May and June and testes were still small. All specimens examined from July to October possessed small ducts.

Seasonal Changes in Females

Mature females were collected in every month from March to October. No specimens were available from November through February. A distinct set of large follicles was present in 103 specimens so that determination of average number and size of follicles was possible during different seasons (Table 2). The *t* test was used to determine if significant differences existed between appropriate pairs of observations (Table 3). The 5 percent level of significance was used.

The number of largest follicles when oviducal eggs were present did not vary significantly in either year from the number present after egg laying. The average follicle size, however, was significantly smaller after egg laying.

In 1965 the number of large follicles in females prior to ovulation did not differ significantly from the number in females containing oviducal eggs. The follicles did increase in size. Both number and size of large follicles increased significantly in females collected in late September and October compared to those collected in July through early September.

Table 2.--Seasonal changes in average number and size of large follicles of *Chrysemys picta* from Wintergreen Lake.

Reproductive State	Dates		Sample Size		Mean Number of Large Follicles		Mean Diameter of Large Follicles (in mm)	
	1965	1966	1965	1966	1965	1966	1965	1966
Prior to ovulation	Apr. 6-May 10 (A)	Mar. 13-May 5 (A)	20	25	7.1	7.7	15.4	15.7
		May 16-May 23 (B)		8		6.8		7.8
Oviducal eggs present	May 26-Jan. 4 (B)	June 4-June 14 (C)	10	7	6.3	4.3	17.0	17.0
After egg laying	July 5-Sep. 8 (C)	July 11-July 29 (D)	16	4	5.6	2.3	12.1	13.1
	Sep. 21-Oct. 27 (D)		8		7.8		14.2	

Table 3.--Results of *t* tests for pairs of observations in Table 2. The 5 percent level of significance was used.

Pair of Observations Tested	Significant Difference Between Average Number of Follicles	Significant Difference Between Average Diameter of Follicles
1965A - 1965B	No	Yes
1965B - 1965C	No	Yes
1965C - 1965D	Yes	Yes
1966A - 1966B	No	Yes
1966B - 1966C	Yes	No
1966A - 1966C	Yes	Yes
1966C - 1966D	No	Yes

Follicle diameters increased significantly in the week before ovulation began in 1966. There was no significant change in the number of follicles. Conversely, in the following two weeks, when ovulation had occurred, the number of large follicles decreased significantly but there was no change in follicle size.

Two female Chrysemys collected on May 14, 1965, had ovulated, as compared to only one of three collected May 23, 1966. No additional specimens were examined until May 26 in 1965, but following that date all mature females contained oviducal eggs or corpora lutea. Seven females dissected between May 16 and 21 apparently had not ovulated in 1966.

Egg deposition in 1965 (eight females observed) commenced on June 5 and continued until June 23 while in 1966 the observed nesting period lasted from June 10 to July 3 on the basis of five individuals recorded. These egg laying dates may be extended to May 28 and July 5 in 1966, since a specimen collected at the earlier date had corpora lutea whereas one at the later date still contained oviducal eggs.

Corpora lutea were present in all of 13 mature females examined during June, 1966, but only one of four had corpora lutea in July. When oviducal eggs were present, the number corresponded to that of the large corpora lutea in all but one instance. Usually the corpora lutea were 4 to 5 mm in diameter. In five turtles a second set was present. These were 1 to 2 mm in diameter.

Mating

Instances of sexual behavior were recorded as they were encountered in the field. Sixteen observations were made; one in March, six in April, five in May, one in August, and three in October. In most instances (14), the activity involved titillation between males and females of larger size; however, on two occasions (March and April) males were observed chasing other males and attempting titillation. Two observations (May) involved attempts by males to restrain the female by biting her plastron.

Reproductive Potential

The average number of oviducal eggs was 6.6 in 1965 and 6.1 in 1966. There was no significant difference between the two years. More than 60 percent of the females contained either six or seven oviducal eggs. Only two of 41 individuals had less than five eggs and only two had more than eight.

The relationship between size of the female and number of oviducal eggs was tested in 41 *Chrysemys*. The 23 turtles less than 130 mm in plastron length (mean length of those in sample) averaged 6.2 oviducal eggs. Those 130 mm or above had an average of 6.7 eggs per individual. A *t* test was run and there was no significant difference between thw two size classes at the 5 percent level ($t = 1.2$ with 39 d.f.).

During the egg laying season of 1966 nesting experiments were conducted with captured animals in an attempt to determine if individuals lay more than one clutch per year. Abnormal egg deposition occurred in all of the turtles, presumably as a result of the experimental conditions. None of the animals dug nests, but, instead, eggs were deposited on the surface. In most instances eggs were laid sporadically, usually no more than one or two per day.

A record was kept of the number of eggs laid and on July 30, all of the turtles were dissected. Oviducal eggs and follicles were counted and follicle diameters were determined in 10 individuals. The results are shown in Table 4.

The average number of eggs laid was 5.7. The total number (eggs laid plus those in the oviducts) averaged 8.7. This was significantly higher than the average clutch size (6.6) of wild females from 1965. Large follicles ranging from 12 to 17 mm and averaging about 14 mm in diameter were present in nine of ten individuals. When the number of large follicles was added to the number of eggs, a total of 13 to 15 was reached. The individual without enlarged follicles had a total of 11 eggs.

Growth Rates

Determination of juvenile growth rates in Sherriff's Marsh was particularly effective because of the large number

Table 4.--Results of nesting experiments during summer of 1966. Numbers in parentheses are averages per turtle in cages having more than one individual.

Turtle	Number of Eggs Laid	Number of Oviducal Eggs on July 30	Number of Large Follicles	Total Number of Eggs	Total Number of Eggs Plus Follicles
1	7	0	6	7	13
2	6	5	0	11	11
3	9	0	5	9	14
4	9	0	-	9	-
5	(4.6)	4	8	(8.3)	(15.0)
6	(4.6)	3	6	(8.3)	(15.0)
7	(4.6)	4	6	(8.3)	(15.0)
8	(4)	4	4	(9.0)	(13.7)
9	(4)	7	3	(9.0)	(13.7)
10	(4)	4	7	(9.0)	(13.7)
11	(5.5)	3	4	(8.0)	-
12	(5.5)	2	-	(8.0)	-
Averages	5.7	4.0	5.4	8.7	13.7

which could be aged. Growth rate could also be determined by measuring the increase in size of individuals recaptured during the period of study.

The mean plastron length, range, and standard deviation for each age class from one to 11 are given in Figure 9. Males over 80 mm in plastron length are not included. Plastron length increased steadily through the 10th year. The 12 turtles in their 11th to 13th years were only slightly larger than those in their 10th year. Excluding turtles in their 11th to 13th years, the increase in mean size in successive years varied from 13.0 mm between the first and second years to 4.3 mm between the fifth and sixth. The average increase in mean size in successive years from one to 10 was 7.7 mm/year.

Regression equations were determined for the 187 juveniles one to four years old and for 31 mature males (Figures 10 and 11). The 95 percent confidence interval for the regression coefficient is 1.96 ± .15 for the juveniles and .203 ± .07 for the males. Average growth rates determined by this method are 9 to 10 mm per year for the young turtles and about 1.1 mm per year for the mature males.

On the basis of recaptures, females 110 mm or more averaged 1.1 mm per year, mature males 1.2 (Table 5). Combining recapture data for both sexes, the average growth rate was 1.1 mm/year. The trend in both sexes was for the

Figure 9.--Age-length relationships of *Chrysemys picta* from Sherriff's Marsh, not including mature males. Vertical lines represent range; horizontal lines represent mean; bars represent standard deviation. Numbers in parentheses are sample sizes.

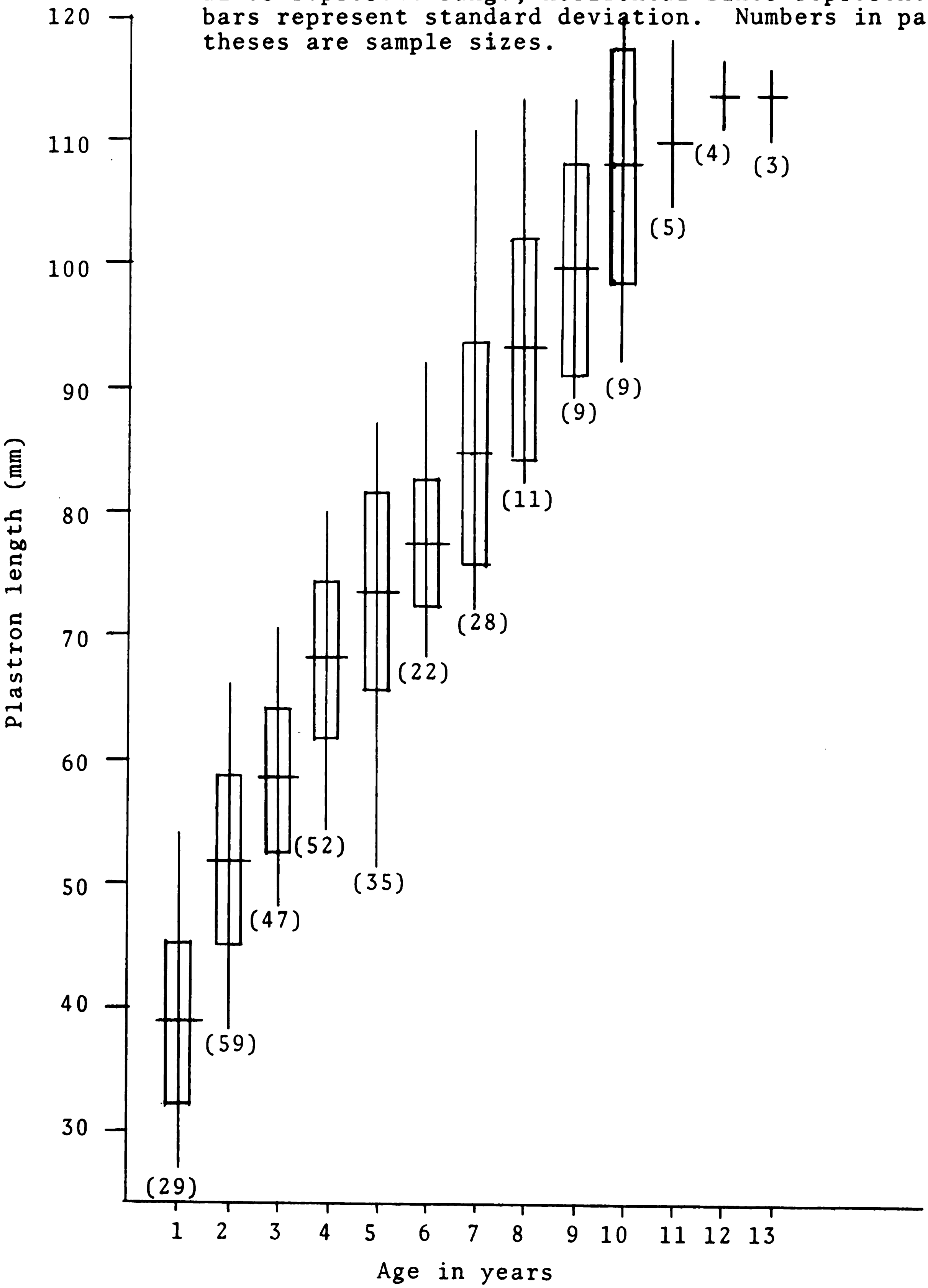


Figure 10.--Relationship between age and plastron length of juvenile *Chrysemys picta* from Sherriff's Marsh. Regression equation is $y = 33.2 + 1.96X$.

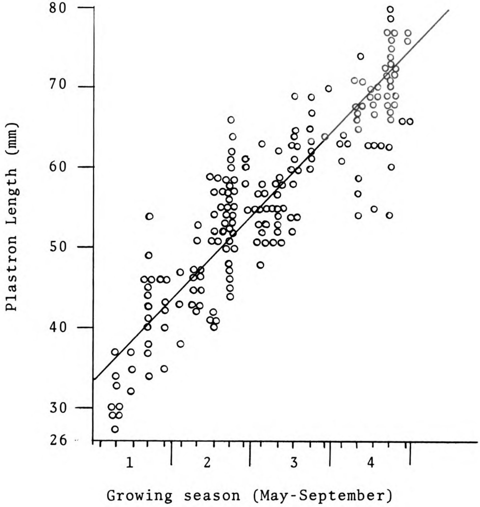


Figure 11.--Relationship between age and plastron length of mature males from Sherriff's Marsh. Regression equation is y = 82.1 + .203X.

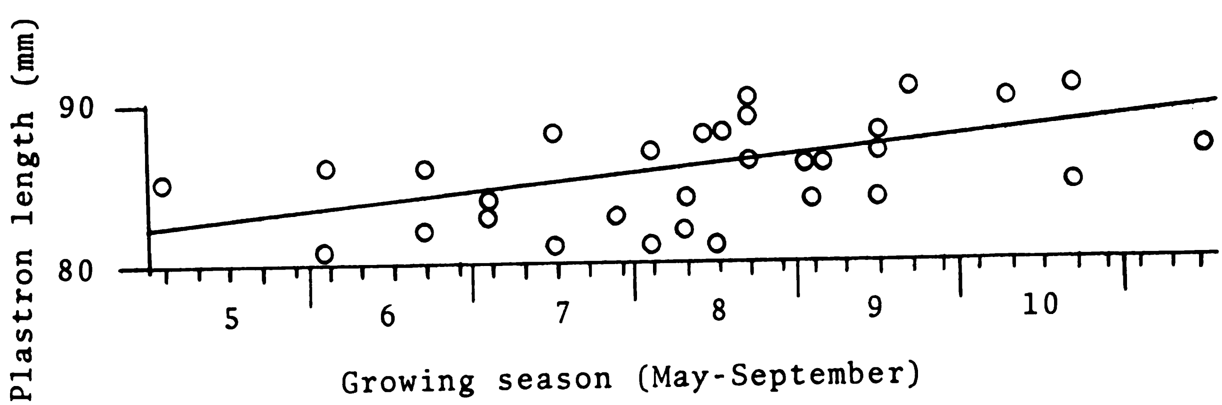


Table 5.--Growth of *Chrysemys picta* in Sherriff's Marsh based on individuals recaptured after more than 75 days during the growing season.

Size Range	Number Recaptured	Number Showing Growth	Cumulative Growth (mm)	Cumulative Number of Growing Seasons Between Original Captures and Recaptures	Average Increase in Length (mm/Growing Season = Year)
Females					
110-114	8	7	13	10.8	1.2
115-119	12	8	17	15.4	1.1
120-133	17	12	23	23.8	1.0
Total	37	27	53	50.0	1.1
Males					
80-89	12	12	28	12.4	2.3
90-99	5	3	5	5.5	.9
100-111	12	5	6	13.8	.4
Total	29	20	39	31.7	1.2
Males and Females Total	66	47	92	81.7	1.1

larger adult size classes to show less growth than smaller ones over comparable lengths of time.

Population Dynamics

Population Size and Density

From July 1964 to October 1966, 1010 *Chrysemys* were marked at Sherriff's Marsh and 408 recaptures were made on 258 marked individuals. The percentage of recaptures generally increased during successive collecting periods from early 1965 to late 1966 (Table 6).

An estimate was made of the number of *Chrysemys* in each size-sex category (Table 7). More than 1400 immature turtles, composing approximately 59 percent of the total population, were estimated (Lincoln Index) to be present in Sherriff's Marsh. The estimated number of mature turtles was 925. Actual captures were 521 (52 percent) immature and 480 (48 percent) mature.

Chrysemys in Sherriff's Marsh were restricted to the 14 acres of open water. The minimum density, derived from the estimate of 2328 individuals, would therefore be 166 turtles per acre. However, approximately four acres of Zone 14 were not utilized by turtles and should not be considered in determining density. Excluding these four acres, this results in a density estimate of 233 *Chrysemys* per acre.

Table 6.-- Recapture ratios of *Chrysemys picta* from Sherriff's Marsh.

Size-sex Category	Collecting period	Total Number Captured	Recapture Percentage
Juveniles less than 80 mm in plastron length	Apr-May 1965	34	.00
	Jun-Jul	71	.06
	Aug-Oct	56	.09
	Mar-May 1966	21	.17
	Jun-Jul	108	.28
	Aug-Oct	85	.30
Immature females 80-114 mm in plastron length	Apr-May 1965	22	.05
	Jun-Jul	44	.23
	Aug-Oct	32	.15
	Mar-May 1966	45	.13
	Jun-Jul	59	.21
	Aug-Oct	39	.23
Mature Males	Apr-May 1965	46	.04
	Jun-Jul	54	.17
	Aug-Oct	43	.22
	Mar-May 1966	86	.22
	Jun-Jul	67	.33
	Aug-Oct	34	.29
Mature Females	Apr-May 1965	54	.07
	Jun-Jul	41	.22
	Aug-Oct	36	.36
	Mar-May 1966	36	.22
	Jun-Jul	57	.23
	Aug-Oct	29	.55

Table 7.--Population size of *Chrysemy picta* in Sherriff's Marsh.

Size-sex Category	Number Estimated	Percentage of All Estimated Individuals	Number Actually Captured	Percentage of All Captured Individuals
Juveniles less than 80 mm in plastron length	862	.37	305	.31
Immature females 80-114 mm in plastron length	541	.23	216	.22
Mature males	490	.21	265	.27
Mature females	435	.19	215	.22
Total	2328		1001	

The density observed by head counts in small, heavily vegetated areas was the equivalent of more than 1000 turtles per acre on many occasions. The highest recorded density was 60 turtles in 54 square meters in Zone 8 on June 9, 1965. This was the equivalent of more than 4000 *Chrysemys* per acre.

Sex Ratio

The sex ratio of mature individuals (males more than 80 mm and females more than 115 mm in plastron length) captured in the marsh was 1.2 males:1.0 females. The ratio estimated by the Lincoln Index was 1.1 males:1.0 females (Table 7). There is no significant difference between the sex ratios determined by the two methods ($x^2 = 0.61$). The sex ratio is not significantly different at the 5 percent level from a 1:1 ratio when based upon the number of estimated individuals ($x^2 = 3.3$), but is significantly different when based upon actual captures ($x^2 = 5.2$).

Age Structure and Survivorship

An estimate was made of the number of individuals in each of the first four age classes by using 1965 as a precensus period and 1966 as a census period (Table 8). Assuming a 1:1 sex ratio, the 1962 through 1965 cohorts were estimated to have the following numbers of turtles of each sex in 1966: 124, 69, 35, and 78.

Table 8.--Number of juvenile *Chrysemys picta* in Sherriff's Marsh.

Age Class	Age in 1965	Number Marked and Re- leased in 1965	Number Originally Captured in 1966	Number Recaptured in 1966	Total Captured in 1966	Number Estimated to be in Population
1965	1	20	41	6	47	157
1964	2	17	19	6	25	70
1963	3	38	39	15	54	137
1962	4	33	30	6	36	198

Due to difficulties in aging and complications brought about by the changes in growth rates as males neared 80 mm a satisfactory estimate of the number of individuals in the 1961 age class was not made.

Age could not be determined by counting annuli in most immature females over 80 mm in length. A general age-length relationship is indicated in Figure 9. Most females between 80 and 89 mm were in their seventh year, although this size range also included some individuals in older and younger age classes. The 90-99 mm size range was composed mostly of eight and nine-year-old animals. The 100-109 mm size range primarily included individuals nine to eleven years old. Essentially, then, the immature females which were 80 to 109 mm in length included almost all females eight or nine years old, more than half of those 10 or 11 years old, about two-thirds of those that were seven years old, and about one-fifth of those five or six years old.

The 80 to 109 mm size range was thereby composed of immature females from the equivalent of approximately four age classes. Since 358 females were estimated to be 80 to 109 mm in length, (Table 9), this size range would average about 90 individuals per age class.

The age-length relationship of adult *Chrysemys* from the marsh is shown in Figure 12 and is based upon a growth

Table 9.--Population size structure of *Chrysemys picta* in Sherriff's Marsh

Size range (plastron length in mm)

Mature males

	80-84	85-89	90-94	95-99	100-104	105-109	110-116	Total
Number captured	38	59	54	46	35	28	5	265
Percentage of total	14.3	22.2	20.4	17.4	13.2	10.6	1.9	
Estimated number based on percentage of 490	70	109	100	85	65	52	9	490

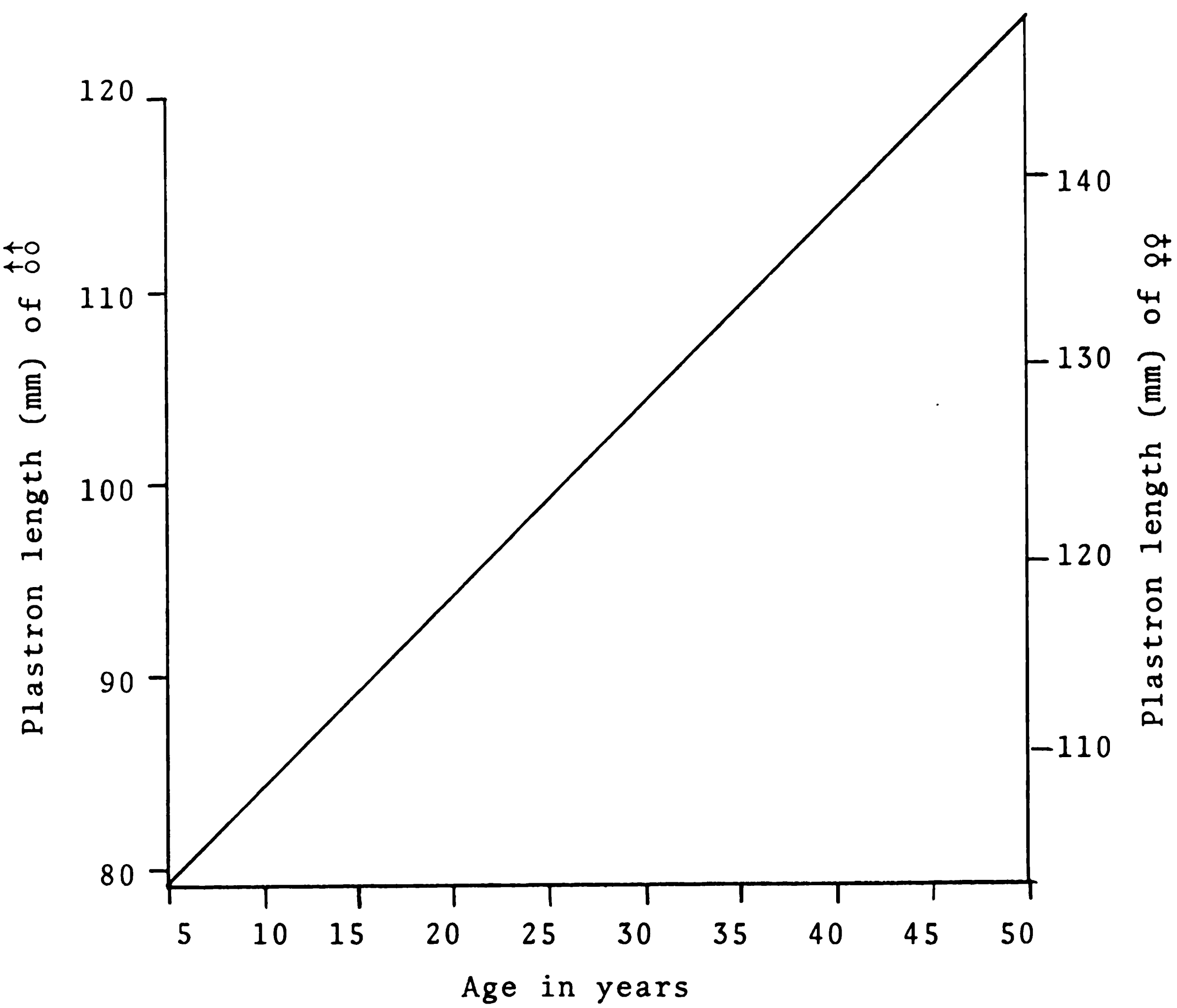
Immature females

	80-89	90-99	100-109	110-114	Total
Number captured	42	42	59	73	216
Percentage of total	19.5	19.5	27.3	33.8	
Estimated number based on percentage of 541	105	105	148	183	541

Mature females

	115-119	120-124	125-129	130-134	135-140	Total
Number captured	83	69	43	15	4	215
Percentage of total	38.6	32.1	20.2	7.0	1.9	
Estimated number based on percentage of 435	168	140	88	30	8	435

Figure 12.--Age-length relationship of *Chrysemys picta* from Sherriff's Marsh based on an estimated growth rate of 1 mm/year.



rate of approximately one mm per year. Consequently, each 5 mm size range should include five age classes. The age structure of the adult population can be estimated using Figure 12 in conjunction with the number of individuals in each 5 mm size range (Table 9). The age structure of the *Chrysemys picta* population in Sherriff's Marsh is shown in Table 10.

Mortality

Twenty-seven *Chrysemys* were found dead in the marsh during the study (Table 11). The animals found in 1964 were scattered around the periphery of Zone 5. The heads were missing on all individuals, and a few were also missing limbs. Slight scratches were present on the shells. The grass was flattened down for a half meter or so around each dead turtle. Some specimens appeared to have been dead less than a day, whereas, others had been deceased for several days. All indications were of a predator such as a mink or raccoon which operated over a period of several days.

The cause of death was uncertain in the turtles from 1965 and 1966, with the exception of the ones from July 15, 1965, and August 2, 1966. Each of these carcasses was missing its head, presumably as a result of predation. The eight dead *Chrysemys* found on May 15, 1965, were heaped together along shore. Only the shells remained and no clue was given as to the cause of death.

Table 10.--Age structure of *Chrysemys picta* population at Sherriff's Marsh. Estimates for years 1 to 4 are based on a Lincoln Index of turtles in which age was known. A 1:1 sex ratio is assumed. The collective estimate for immature females 6-11 years old was derived from the age-length relationships (Figure 9) and the estimated number in each size class (Table 9). Estimates of mature turtles were based on a growth rate of 1.0mm/year for both sexes and on the number estimated to be in each size class.

Males			Females		
Plastron Length in mm	Age in 1965	Estimated Number/ Age Class	Plastron Length in mm	Age in 1965	Estimated Number/ Age Class
	1	79		1	79
	2	35		2	35
	3	69		3	69
	4	99		4	99
80-84	6-10	14.0		6-11	90
85-89	11-15	21.8	110-114	12-16	36.6
90-94	16-20	20.0	115-119	17-21	34.6
95-99	21-25	15.0	120-124	22-26	27.0
100-104	26-30	13.0	125-129	27-31	17.6
105-109	31-35	10.4	130-134	32-36	6.0
110-116	36-41	2.5	135-140	37-42	1.3

Table 11.--*Chrysemys picta* found dead in Sherriff's Marsh.

Number of Dead Turtles	Date Found	Length (mm)	Sex	Zone	Previously Captured
1964					
6	July 3	75,83,107, 109,115,129	--	5	No
3	July 3	--	--	5	No
1	August 3	90	--	5	No
1965					
1	May 8	39	--	6	No
8	May 15	70,84,94, 106,106, 109,112,133	--	16	No
1	July 15	125	F	5	No
1	October 12	116	F	8	Yes
1966					
1	April 5	130	F	3	No
1	June 10	68	--	8	No
1	July 4	58	--	11	No
1	August 2	115	F	4	Yes
1	August 19	119	F	14	Yes
1	August 29	109	M	5	No

Predators were a major source of mortality on eggs in the nest. The fate of seven of nine nests, whose construction was observed in 1965, was predation by mammals. Four of these were destroyed the night following egg laying; the other three were not disturbed until at least two weeks later. Numerous examples of predation on nests which had not been previously located were noted throughout each summer. In 1966 four nests were covered with hardware cloth immediately after the female left the nest site. All eggs hatched successfully in two of these. In one of the other nests eight eggs did not hatch and the single hatchling died. Two eggs hatched successfully and two hatchlings died in the remaining nest.

Seasonal Activity

Aquatic

Swim-in traps: The swim-in traps in Sherriff's Marsh served as indicators of the seasonal activity of *Chrysemys*, based on the assumption that increased movement and activity in the population was reflected in an increase in trap captures. The ratio of the number of *Chrysemys* captured in swim-in traps to the number of these traps checked was determined for selected periods in 1966 (Table 12). The activity in March was followed by a period of inactivity in early April. The capture ratio during the second half of April was

Table 12.--Percentage of *Chrysemys picta* captured in swim-in traps in *Sherriff's Marsh* during 1966.

Dates	Males	Females	Total	Number of Traps Checked	Capture Percentage
March 14-22	4	4	8	36	21
April 5-11	0	0	0	17	0
April 15-30	13	2	15	65	23
May 3-14	8	4	12	22	55
May 18-23	0	0	0	30	0
May 25-June 10	11	16	27	46	59
June 20-27	5	8	14*	34	41
July 4-28	7	14	21	59	36
August 2-29	7	11	18	61	30
September 7	0	0	0	10	0
October 17	0	1	1	7	14

*Includes one juvenile.

similar to that of March. In the first two weeks of May the ratio more than doubled that of the preceding two weeks only to be followed by a week with no trap captures. Late May and early June had the highest capture ratio of the summer. After June 20 the ratio declined steadily.

A single trap in the outlet channel of Wintergreen Lake in 1966 showed a trend similar to that of the marsh traps. A brief period of activity from March 17-22 was followed by three weeks in which no turtles were captured (Table 13). Another period of increased activity began on April 15. No turtles were caught in the Wintergreen Lake trap after April 22.

Only one swim-in trap, placed near the eastern entrance to Zone 5, was used extensively in the marsh during 1965. This trap had a smaller, more funnel-shaped entrance than other traps, and an enclosed top. Few, if any, turtles escaped once they had entered the trap. At least one *Chrysemys* was captured in this trap on each day it was checked from July 15 to August 31 (Table 14). Only three individuals were caught during 13 collecting days in September and October.

Three swim-in traps were in the entrances to Zone 5 from March to October 1966. Although a few individuals were captured sporadically after the middle of March, consistent captures in these traps did not result until June (Table 15). During the summer months the traps in Zone 5

Table 13.--*Chrysemys picta* collected in swim-in trap located in the outlet of Wintergreen Lake during spring of 1965.

Date	Males	Females	Total
March 17	0	2	2
18	0	1	1
21	1	1	2
22	2	2	4
23,24, 25,26, 28,31	0	0	0
April 2,4, 7,11	0	0	0
15	1	1	3*
16	3	5	8
20	4	2	6
22	0	1	0
25,28,30	0	0	0

*Includes one juvenile

Table 14.--*Chrysemys picta* collected in the swim-in trap in Zone 5 of Sherriff's Marsh during 1965.

Date		Males	Females	Total
July	15	5	5	11*
	16	1	0	1
	17	0	3	3
	18	1	1	2
	23	2	5	7
	26	0	3	3
	28	2	3	5
Aug.	4	0	4	4
	11	3	3	6
	14	4	3	7
	21	3	3	6
	23	2	4	6
	24	0	1	1
	28	3	4	7
	31	0	0	0
Sept.	2,5, 11,12	0	0	0
	21	0	2	2
	23,27	0	0	0
Oct.	5	0	1	1
	12,19, 23,27, 28	0	0	0

*Includes one juvenile

Table 15.--*Chrysemys picta* captured in three swim-in traps in entrances to Zone 5 in Sherriff's Marsh during 1966.

Date		Males	Females	Total
March	14	0	0	0
	17	0	0	0
	21	1	0	1
	22	1	1	2
April	5,11,15	0	0	0
	17	1	1	2
	22	1	0	1
	25,28,30	0	0	0
May	3	0	0	0
	7	0	1	1
	14	0	1	1
	18,20,21, 23	0	0	0
	25	1	1	2
June	1	1	4	5
	2	1	0	1
	7	1	2	3
	10	1	4	5
	20	0	2	2
	22	0	0	0
	26	1	2	3
	27	0	0	0
July	4	1	3	4
	6	1	4	5
	15	0	0	0
	16	1	1	2
	18	0	0	0
	25	1	0	1
	28	0	1	1
Aug.	2	0	0	0
	9	1	0	1
	13	0	2	2
	19	1	0	1
	24	0	1	1
	29	1	1	2
Sept.	7	0	0	0
Oct.	17	0	1	1

yielded 39 Chrysemys in 21 collecting trips. The traps were not checked extensively after August.

Baited traps: During the spring of 1965, 33 Chrysemys were collected in baited traps at Sherriff's Marsh (Table 16). All but two of the turtles were caught between April 29 and May 11, though many traps were set before and after these dates.

Head counts: One indication of activity was the number of heads visible at the water's surface. Head counts for three equal areas of water in the marsh during 1965 are given in Table 17. The two areas in Zone 8 were within 50 meters of each other and differed primarily in that one had surface vegetation and the other did not. The area in Zone 5 lacked surface vegetation. Both the area in Zone 5 and the area with surface vegetation in Zone 8 averaged more than 15 heads per observation in June and July. The other area in Zone 8 averaged less than one head per observation in June. Head counts began to decrease during August and no turtles were observed after September 23 in any of the areas. Two heads were seen at the surface during a two hour period at the marsh on March 17, 1966, but none were observed on March 21, April 5, or April 11. Approximately a dozen heads were seen in a two hour period on April 15. Most of these animals were in masses of algae floating at the surface. Comparative head counts were made in four Zones on July 25, 1966 (Table 18). The most heads

Table 16.--*Chrysemys picta* captured in baited traps at Sherriff's Marsh during 1965.

Date		Number of Traps Set	Total Trap Hours	Number of Captures			Number Captured Per Trap Hour
				Males	Females	Total	
March	17	1	1			0	0
	24	1	1			0	0
	27-28	2	42			0	0
April	24	1	29			0	0
	25	1	19			0	0
	29	6	35	3	2	5	.14
May	1-2	6	130	4	9	13	.07
	4	1	5	0	1	1	.20
	8-9	10	360	2	8	10	.03
	11	11	64	0	2	2	.03
	15-16	8	168			0	0
	21	2	14	0	1	1	.07
	22	-	-	0	1	0	-
	25	1	-			0	0
	31	3	-			0	0
June	9	4	36			0	0

Table 17.--Head count observations of *Chrysemys picta* from three areas in Sherriff's Marsh during 1965.

Date		Zone 5 (Surface Vegetation Present)	Zone 8 (Surface Vegetation Present)	Zone 8 (No Surface Vegetation
June	9	16	60	0
	12	8	18	0
	13	8	15	0
	20	18	11	0
	22	2	4	1
	26	9	15	2
	29	24	-	-
	30	6	3	0
July	4	21	17	-
	8	23	32	-
	15	40	-	-
	16	8	-	-
Aug.	4	6	-	-
	24	0	-	-
	28	0	4	1
Sept.	2	6	-	-
	5	0	5	1
	12	2	3	0
	21	0	3	1
	23	3	0	0
	27	0	0	0
Oct.	5,12,13,19, 23,27,28,31	0	0	0

Table 18.--Head counts of *Chrysemys picta* in four Zones in Sherriff's Marsh on July 25, 1966. (At this time Zones 2 and 5 were completely covered with duckweeds. Zones 3 and 4 had very little surface vegetation.)

Zone	Number of Heads Counted
2	31
3	13
4	3
5	171

were seen in the two zones with abundant surface vegetation. Head counts were made for all of Zone 5 on August 13, 19, and 29. These were respectively 106, less than 25, and less than 15. This shows a steady decline from the 171 of July 25.

Basking: Although basking activity was not observed in a quantitative fashion, field notes taken at Sherriff's Marsh indicate certain trends. Considerably more *Chrysemys* were seen basking in April than in any other month. Basking occurred throughout the summer and early fall but in most instances the number of turtles basking was but a small proportion of those seen in the water. Few or no turtles were seen basking in the marsh on windy days, regardless of cloud cover or air temperature.

Observations of juveniles: Since smaller individuals were usually not collected in any of the traps, an indication of juvenile seasonal activity must necessarily be based on either observation or hand collecting. One trend which was prevalent in 1965 and 1966 was that individuals in the third and fourth growing seasons were first collected in early May, two-year-olds were first collected in late May. Young of the year were neither seen nor collected in Sherriff's Marsh until middle June in 1965 and late July in 1966. Individuals in each age group were collected regularly after the dates of their first appearance until middle September of both years.

Observations at low temperatures: On two occasions during the study period large numbers of _Chrysemys_ were observed on the bottom of Wintergreen Lake. More than 100 were seen in 10 minutes on April 6, 1965, in an area of about 600 square meters. Most of the lake was frozen at this time and turtles were sought only in the area of open water. Many disappeared into the bottom silt when the boat approached, others swam slowly away. A sample was taken of which 20 were mature males, 13 mature females, and 2 immature females. Only a single _Chrysemys_ was seen in Sherriff's Marsh in the four-hour period preceding the observation at Wintergreen Lake. The water temperature was 4° C at both localities.

A similar phenomenon to the above was observed on December 15, 1966, beneath newly-formed ice at Wintergreen Lake. The turtles behaved as they had in April. They were in the same place as before, however, the remainder of the lake was not investigated. It was not determined, therefore, if the activity was localized in that part of the lake. A collection of 21 contained 5 mature males, 14 mature females, and 2 immature females. Other observations of _Chrysemys_ at water temperatures of 4° C were of single individuals on January 3 and November 29, 1965, and January 8, 1966.

The bottom in three areas in the marsh was searched for turtles on October 17, 1966. An underwater suit was used and the collector probed at least 50 cm into the slit and mud. Many parts of the marsh still had thick clumps of *Ceratophyllum* and *Chara*, and could not be investigated by this method. Turtles were neither seen nor collected. The following areas were examined: approximately 500 in Zone 5, about 300 m^2 in Zone 9; and about 200 m^2 in Zone 13.

Terrestrial

A record was kept of all *Chrysemys* seen on land in an attempt to quantitatively evaluate the periods of terrestrial activity. Early spring travel occurred during both years (Table 19). The 10 specimens from late April and early May 1966 were represented by mature males and females and by immature individuals. After the first week in May of each year, there was a two-week interval in which no turtles were sighted on land. A few individuals were again seen during late May of both years. A total of 29 were found on land during June and July of 1965 and 1966. All of these were mature females. No *Chrysemys* were observed on land in late July or August. Fall travels were not recorded in 1966, but three *Chrysemys* were seen crossing roads in middle September 1965.

Terrestrial drift fences for hatchlings were set up in early March of 1966 in five areas around Wintergreen Lake. Three of the fences were 15 meters long and two were 30. No *Chrysemys* hatchlings were trapped between March 13

Table 19.--Records of *Chrysemys picta* found on land from May 2, 1965, to June 20, 1966.

Date	Mature Females	Mature Males	Immature Females	Other Juveniles	Total
1965					
May 2-8	2	2			4
May 25-31	2	1	1		4
June 1-July 9	14				14
Sept. 17-21	1	1		1	3
1966					
April 20-May 6	2	2	1	2	10*
May 21-26			2		2
June 4-20	15				15

*Includes three individuals over 80 mm in which sex and state of maturity were not determined.

and April 19. The first hatchling was collected on April 20, and traps were checked every day thereafter until May 7. Baby turtles were captured on April 21 (1), April 24 (3), May 5 (1), and May 6 (1). Traps were checked on seven days between May 7 and May 24, but no more turtles were collected.

Local Travel in Sherriff's Marsh

Less than 15 percent of the *Chrysemys* recaptured in Sherriff's Marsh changed zones and traveled more than 100 meters during a single summer (Table 20). There were no significant differences between the distances traveled by mature males, mature females, and immature individuals.

Between successive summers, mature females changed zones and traveled distances of more than 100 meters significantly more than mature males ($X^2 = 7.5$) or immature individuals ($X^2 = 6.0$). Travel by mature males between successive summers was not significantly different from that by immature turtles ($X^2 = 1.7$).

Mature females also traveled interzonally more often than males or immature individuals, based on all recaptures throughout the study (Table 21). Over 30 percent of all recaptured females had traveled to a non-adjacent zone, whereas this was true for less than 20 percent of all other turtles.

Thirteen of the 16 individuals recorded as traveling 400 meters or more were females, nine of them mature (Table

Table 20.--*Chrysemys picta* which changed zones in Sherriff's Marsh and traveled more than 100 meters.

	Number Recaptured	Percentage Changing Zones and Traveling 100 Meters
During single summer		
Immature	58	12
Mature Males	19	5
Mature Females	23	13
Between successive summers		
Immature	70	17
Mature Males	19	5
Mature Females	21	43

Table 21.--*Chrysemys picta* from Sherriff's Marsh which were recaptured in the same or an adjacent zone each time (O) compared with those which were recaptured at least once in a non-adjacent zone (N).

	Immature		Mature Males		Mature Females		Total	
	O	N	O	O	O	N	O	N
Number	95	19	66	15	44	20	205	54
Percentage	83	17	81	19	69	31	79	21

22). Four of the trips were made in less than three weeks time, one immature female traveling 600 meters in a maximum of eight days. The longest distance traveled by any turtle during the study was that of a mature female captured crossing the road north of the marsh on July 4, 1965, and recaptured on August 19, 1966, a straight-line distance of more than one kilometer.

Twenty males were captured two or more times in a single spring (March to early May); thirteen were taken in the same zone each time they were captured while seven had changed zones and moved 150-500 meters. One of these animals, captured four times in the spring of 1965, was in a different zone each time. Interzonal travel by males in the spring-time was significantly higher at the 5 percent level than travel in the summer (X^2 = 5.29).

Table 22.--*Chrysemys picta* from Sherriff's Marsh recorded as traveling more than 400 meters.

Sex	Distance Traveled (m)	Zone of Original Capture	Zone of Recapture	Number of Days Between Captures
F	1100	15	14	411
J	800	3	11	327
F	760	5	14	100
F (imm)	750	5	14	307
F (imm)	620	3	9	20
F (imm)	600	2	8	8
F	500	5	2	382
M	500	9	13	13
F	470	3	8	303
F	470	5	2	743
F	460	5	2	392
F	460	5	2	710
F	460	5	2	322
F (imm)	440	5	2	409
F	400	9	13	19
M	400	7	9	49

DISCUSSION

Reproduction

Size and Age at Maturity

Reproductive maturity in turtles is correlated with either age (Risley 1938) or with length (Hildebrand 1932; Cagle 1948, 1954). Cagle (1948) commented that male *Pseudemys scripta troosti* from two Illinois populations reached maturity at about the same size although their growth rates, and hence age, were different. Tinkle (1961), on the other hand, found that *Sternothaerus odoratus* males from different geographical localities reached maturity at different lengths but at the same age. Whether Tinkle's findings are a result of geographic variation or a difference between sternothaerine and emydine turtles is not known.

Age-length maturity relationships in *Chrysemys picta* from Wintergreen Lake and Sherriff's Marsh indicated that sexual maturity is correlated with length, not age, at these localities. Males from both the lake and the marsh reach maturity at a plastron length of approximately 80 mm. The average growing seasons at which these lengths are reached differ in the two populations, being the fourth year of age in turtles from the lake and the sixth year in those from the marsh.

Cagle (1954) stated that males from northern Michigan reach maturity at about 90 mm and those from Illinois at about 70 mm. Since the populations of the present study are geographically intermediate between Cagle's two populations, the size at which maturity is attained in males may decrease southward. This possible geographical trend is strengthened by Cagle's mention of two Louisiana males around 60 mm which were mature. However, the appearance of a geographical trend must be considered with caution since Cagle's presentation of data in scatter diagrams shows no males between 75 and 85 mm from his Michigan population and only two below 75 mm from his Illinois population. A statement cannot be made with certainty, on the basis of the data shown, that most males from these populations do not reach maturity between 75 and 80 mm, the same as *Chrysemys* males from Wintergreen Lake and Sherriff's Marsh.

Some Sherriff's Marsh females as old as 12 years were immature whereas certain seven year old individuals from Wintergreen Lake were mature. Maturity in most instances coincides with plastron length within a narrow size range at both localities.

The transition zone from the immature to the mature state appears to be between 110 and 120 mm. As a working definition, a plastron length of 115 mm will be considered as the size at which *Chrysemys picta* from this region reach maturity. This varies from results obtained by Cagle (1954) who stated that *Chrysemys* females reached maturity at a plastron length of 120 to 130 mm. Other than possible geographical differences, no explanation for this disparity is readily available.

Seasonal Changes in Males

Annual changes in the testes of turtles have been investigated quantitatively in *Sternothaerus odoratus* (Risley 1938) and *Terrapene carolina* (Altland 1951). These investigators also determined the spermatogenetic cycle. Changes in the testes of *Chrysemys picta*, based on the present study, are similar to those of *Sternothaerus* and *Terrapene*.

Testicular changes in *Chrysemys* may be conveniently classed in two or possibly three seasonal categories. The testes are reduced in size from March through early June. The sperm ducts are enlarged and filled with sperm during part of this spring phase, primarily in April. By late May and June the ducts are small, presumably because mating has occurred and the sperm released.

Late June is a transitional period in which the testes begin to enlarge. In *Sternothaerus*, *Terrapene*, and presumably in *Chrysemys*, this is a result of the beginning of spermatogenesis. Spermatogenesis reaches a peak in the summer phase, which lasts from July through September in *Chrysemys*. Apparently all spermatozoa remain in the testes,

resulting in the extremely large size of testes and small size of the ducts during this period.

October is the transitional period following the summer phase. At this time the testes are beginning to diminish in size, presumably because of the cessation of spermatogenesis and the passage of spermatozoa into the epididymis as is true of *Sternothaerus*.

A winter phase is suggested on the basis of three Wintergreen Lake *Chrysemys* which were dissected in January. This phase is apparently one of small testes and ducts with most of the sperm being contained in the epididymis. Risley (1938) found that the epididymis in *Sternothaerus* was largest during the winter. Presumably there is a third transitional period when the sperm pass from the epididymis to the vas deferens in preparation for the breeding season.

Seasonal Changes in Females

The female reproductive cycle basically consists of enlargement of the follicles, ovulation, and egg laying. The follicles are smallest in the period from July to September. The largest follicles at this time are about 12 to 13 mm in diameter and undoubtedly represent the potential eggs for the following May. The follicles change very little in size during the summer but in September they begin to increase in diameter.

No specimens were available from November through February but specimens in March contained follicles 15 to

16 mm in diameter. The follicles remain this size until May. Eight specimens in 1966 were examined the week preceding ovulation and the largest follicles were found to be almost 18 mm in diameter, greater than for any other time. Presumably, then, follicles undergo a rapid growth immediately before ovulation.

During the time when oviducal eggs were present the follicles averaged 17 mm in diameter both years. These observations were made in late May and early June. These enlarged follicles may represent second cluthes which would have been laid in late June or July.

The fluctuation in average number of follicles which was apparent throughout both sampling years was probably artificial in some instances. Determining which follicles in July and August actually belong to the largest set is often difficult due to their overall small size. Hence, certain follicles which appear much smaller than those in the largest set might increase enough in size to be ovulated the following spring.

Follicular atresion has been observed in box turtles by Altland (1951). There is no direct evidence of atresion in *Chrysemys* of the present study; however, in both 1965 and 1966 the average number of oviducal eggs was smaller than the average number of enlarged follicles in the spring. The lower number of eggs is possibly the result of some follicles not ovulating properly.

Ovulation occurred as early as the second week in May. Most females had ovulated by June. An idea of how long the eggs are retained after ovulation is afforded by comparing known egg laying dates with the times when oviducal eggs were present. In 1966 ovulation was not observed before May 23 but females were seen laying eggs on June 10. This indicates that the oviducal eggs were retained less than three weeks. On the other hand, females were still laying eggs in the first week of July. This indicates egg retention of more than six weeks, unless more than one clutch is laid.

The time of the first ovulation appeared to be about a week earlier in 1965 than in 1966. No turtles were dissected between May 14 and May 26, 1965, so whether ovulation was in effect throughout this period is not known. However, the two Chrysemys collected May 14, 1965, had oviducal eggs whereas none of seven collected from May 16 through 21, 1966, had ovulated.

If ovulation actually occurred earlier in 1965 the most obvious causal factor would be temperature, since warm temperatures prevailed in May, 1965. Whether such a hastening of ovulation could result in an extra clutch being laid is unknown.

Mating

Mating apparently begins as early as March and lasts through May. Based on the appearance of the sperm ducts, sperm transfer could be effected during April or early May. Courtship behavior is negligible during the summer, but in the fall courtship again occurs though apparently not at the intensity observed in the spring.

Reports of other workers on *Chrysemys* indicate both spring and fall courtship. Taylor (1933) reported titillation by several laboratory males on October 16. No instance of copulation was observed. Finneran (1948) noted copulation in a pair of *Chrysemys* on May 2.

Cagle (1955) observed hatchling *Graptemys* and *Pseudemys* titillating in the laboratory. He pointed out that this occurred in immature individuals incapable of "attaining the assumed goal." He suggested that sex hormones are probably the usual cause of such behavior. Assuming this to be true, such male sex hormones are possibly activated in the fall when the mature male turtle is undergoing testicular changes, so that, although courtship behavior and even copulation may occur, there is no sperm transfer.

Reproductive Potential

The annual reproductive potential may be considered as being the number of eggs a female is capable of laying in a year. In *Chrysemys picta* of the present study mature females averaged a minimum of 6 or 7 eggs per season. This figure can probably be doubled, since several lines of evidence indicate that there are two clutches per year:

(1) Ovulation occurs during the third or fourth weeks in May and egg laying begins by the first week in June and lasts until the first week in July. It is unlikely that oviducal eggs would be retained less than three weeks in some individuals but more than six in others. Instead, eggs are probably retained 2 to 3 weeks after ovulation and then deposited. A few days later ovulation might occur again and these eggs are also deposited in 2 to 3 weeks. Such a schedule coincides with nesting observations.

(2) Two size groups of corpora lutea were often present in females in late June and July. Since corpora lutea are no longer visible in August and September, the small group would not be a holdover from the previous year. Also, two groups were not observed in early June before a second ovulation could have occurred.

(3) In females with oviducal eggs in early June there was always a set of follicles of a size large enough for ovulation. Since follicles this large are not present in females after the egg laying period, they are presumably ovulated.

(4) The experimental animals used in controlled nesting studies produced a significantly greater number of eggs per individual than normal (Table

4). Also, upon dissection in late July many of these females had follicles which appeared large enough for ovulation. When the number of these follicles was added to the number of eggs produced by an individual, the resulting total was approximately double that of the average number of oviducal eggs normally found.

The evidence is greatly in favor of two clutches per year though no female under natural conditions was observed laying eggs twice. The size of the second clutch is apparently similar to the first. Two clutches seem to be the maximum for one year. Egg laying in alternate years, as is true of some reptiles (Tinkle 1962; Wharton 1966), is not characteristic of *Chrysemys*. Thus, reproductive potential for female *Chrysemys picta* from southwestern Michigan is apparently 13 or 14 eggs per year.

Cagle (1944b) reported older *Pseudemys* with senile ovaries. A difference between the ovaries of old and young mature female *Chrysemys* was not observed in the present study, indicating that reproductive potential is constant with size and age of the female.

Growth Rates

Immature *Chrysemys picta* grow at a relatively steady rate which decreases markedly when maturity is reached.

Growth rates are similar for each of the immature age classes, but the fastest growth rates were observed between hatching and the end of the second year. After the second year, immature turtles at Sherriff's Marsh increase in plastron length at an average rate of 7 to 8 mm per year.

A striking reduction in growth rate occurs when females reach about 110 mm and males about 80 mm in length. Growth rates in mature turtles were approximately 1 mm per year. This estimate was obtained both from the regression line of age-length relationships in a series of males (Figure 11) and by means of the recapture method (Table 5). Females in different size categories were found to have similar growth rates with a slight reduction in the larger ones. The estimates for the different size classes of males, however, were less homogeneous. The smaller males had growth rates of more than 2 mm per year, whereas, the large ones grew less than .5 mm per year. There is a slight discrepancy between the growth rate of smaller males estimated from the regression line (about 1.1 mm/year) and that estimated by the recapture method. The former figure was based on a much greater sample size and hence is a more accurate method. Therefore, 2.3 mm per year is very likely an overestimate of average growth rate in smaller males. The data are insufficient to satisfactorily quantify growth rates of the various size classes, but the indication is that larger <u>Chrysemys</u> increase more slowly in plastron length than smaller ones.

Population Dynamics

Sex Ratio

The sex ratio of mature *Chrysemys picta* from Sherriff's Marsh was close to a 1:1 ratio. This was true on the basis of actual captures and upon Lincoln Index estimates.

The slightly greater apparent abundance of mature males is probably only a result of the method of determining maturity in females. A plastron length of 115 mm was chosen to represent the size at which most females reach maturity. The length was arbitrarily picked from a relatively narrow size range. A length of 113 or 114 mm could just as easily have been used as a standard length for the size at which females reach maturity. In reality, then, the sex ratio of mature *Chrysemys picta* in Sherriff's Marsh probably does not vary significantly from 1:1.

Age Structure and Survivorship

According to the Lincoln Index technique, an average of 140 turtles were estimated to be in each of the first four age classes at Sherriff's Marsh in 1965 (Table 8). There was no trend towards reduction in numbers during successive years. One cohort (hatchlings from 1964) had fewer individuals than any of the others. Presumably before their second year this cohort suffered from a source of mortality which did not affect older juveniles to the same extent. The collective estimate for immature females 6 to 11 years old was 90 individuals per age class. This is in accord with the estimates for the younger juveniles. There is no evidence to indicate that mortality increases with age in immature *Chrysemys*. Apparently, then, once a juvenile has completed his first year his chances of reaching maturity are extremely high.

The survival pattern from the egg stage until maturity assumes that of a Type IV survivorship curve (Slobodkin 1963). Around 2 percent of the eggs laid at Sherriff's Marsh develop into juveniles which become recruited into the population. Most of these juveniles reach maturity. There are at least three possible causes of mortality in the nest. (1) Non-hatching of *Chrysemys* eggs was observed both in the field and laboratory. This may be due in some part to infertility, as has been observed for *Malaclemmys* (Hildebrand 1929). (2) Extreme environmental conditions such as excessive heat, cold, moisture, or dryness seem likely sources of mortality, although insufficient data were collected to support this postulation. (3) Predation is a major mortality factor at the egg stage. The amount of predation is no doubt excessive under some circumstances, as when a large number of females lay their eggs in one area.

Adults of both sexes experience a much higher mortality rate than is true of immature turtles. There appears to be a sudden reduction in the number of individuals per age class as maturity is approached. This phenomenon may be a result of the method of age determination. Growth rate was assumed to be 1 mm per year for all ages of both sexes. The ages in Table 10 were based upon this age-length relationship. However, old adults probably grow more slowly than young ones. If differential growth rates were taken into account, the smaller size ranges in Table 10 would include fewer age classes than the larger ones. The effect of this would be to raise the number of adults per age class in the younger turtles. The number of individuals per age class would be reduced for older turtles. The resulting survivorship curves for both sexes would then approach a Type III, as defined by Slobodkin (1963). Such a curve is characterized by a constant mortality rate for individuals of all ages. Once a Chrysemys reaches maturity at Sherriff's Marsh, its chances of survival presumably remain the same regardless of age.

Many physiological and behavioral changes accompany maturity. Some of the more obvious effects are increased activity in the spring, expenditure of energy for reproductive functions, and a greater likelihood of terrestrial activity. These and other changes associated with adulthood make mature Chrysemys susceptible to environmental hazards.

that do not confront immature individuals. The result is a much higher adult mortality rate.

Longevity: Turtles are usually considered to be long-lived animals. Carr (1952) states that the age attained by turtles is "perhaps the grestest of any living vertebrate." Hildebrand (1929) gives a "conservative estimate" that Malaclemmys live 25 to 40+ years. Cagle (1950) states that Pseudemys under natural conditions may have a life span "possibly within the range of 50-75 years." Nichols (1939b) estimated that Terrapene carolina were fully grown in about 20 years but that some of the older ones were probably as much as 80 years old. Schneck (1886) reports an individual Terrapene which was marked in 1824 and recaptured several times during the next 60 years. Turtles are always among the oldest vertebrates in zoos (Flower 1944; Conant and Hudson 1949).

Once a Chrysemys hatchling is incorporated into the Sherriff's Marsh population the chances of reaching maturity appear to be excellent. Therefore, most males live at least six years, females at least twelve. In spite of the increased mortality of adults at least 20 percent of each sex probably reach an age of 20 years or more (Table 10). A few individuals were estimated to be over 40 years old. Due to the difficulty of aging old individuals, this is very likely a minimum estimate. There is no indication that Chrysemys at Sherriff's Marsh approach the "maximum life span" for the species(Deevey 1947).

Mortality

Predation on turtles and turtle eggs is a recognized source of mortality (Cagle, 1944c and 1950; Stophlet 1947; Woodbury and Hardy 1948; Carr 1952; Murphy 1964). Egg predation by mammals (presumably raccoons, skunks, or foxes) is undoubtedly of major importance in the *Chrysemys* populations of the present study. The observed predation on juveniles and adults, however, was extremely limited. Whether predation is a constant and important cause of mortality at this level is uncertain.

Parasitism, external or internal, does not appear to be a mortality factor. Although numerous *Chrysemys* individuals carried leeches (*Placobdella* sp.), no heavy infestations were found. The turtles appeared unaffected by the parasites. Although several species of internal parasites were found to be present in juvenile *Chrysemys* from Wintergreen Lake (Esch and Gibbons 1967), the turtles showed no ill effects. Adult *Chrysemys* harbored very few or no internal parasites, whereas one to four year olds were often heavily infested.

Death due to unknown causes was evident both in the nests and in the turtles at Sherriff's Marsh. Eggs and hatchlings died in some nests for no apparent reason, whereas others in the same nest survived. Infertile eggs are a possible cause for some non-hatching (Hildebrand 1929), but the extent of infertility in natural populations of turtles is unknown. Several of the dead *Chrysemys* found at Sherriff's Marsh had not died as a result of predation, but no clue was given to the cause of death. "Old age" has been described in *Pseudemys* (Cagle 1950), but this condition was not observed in any *Chrysemys*. Death from environmental causes resulting in freezing, desiccation, or over-heating does not seem likely in the adults from the marsh population.

Seasonal Activity

Aquatic

Cagle (1954) stated that temperatures of 20 to 25° C are probably optimum for *Chrysemys*. Temperatures around 40° C are usually fatal (Hutchison, Vinegar and Kosh 1966). *Chrysemys* are generally considered to become active at water temperatures about 8 to 11° C (Cagle 1954; Musacchia 1959; Sexton 1959a), which occurred in early spring at Sherriff's Marsh. Adults were first abundant in the middle of March, 1966, when water temperatures reached 10° C. They completely disappeared in late March when temperatures dropped to 5° C and did not reappear until temperatures reached 8° C in April. The effect of temperature in the fall was not as well defined. Water temperatures were generally above 10° C in September and early October of 1965 and 1966. Yet turtles became increasingly less abundant.

Activity at low temperatures in the fall is considerably reduced.

Juveniles became active several weeks later than adults. Time of emergence in the spring varied among the juvenile age classes, with the older individuals appearing first. Although hatchlings were known to enter the water in April and May of 1966, none were seen in the marsh until late July. Younger turtles do not become active when water temperatures reach the minimum for activity.

Hunger does not seem a likely motivation for the early spring activity of adults for three reasons: (1) only large turtles were active early. If hunger were the reason for vernal activity, smaller juveniles, having a higher metabolic rate, should be the first to appear, not the last. (2) *Chrysemys* are not known to feed extensively at temperatures below 15° C (Sexton 1959a). (3) *Chrysemys* were not collected in bait traps in Sherriff's Marsh until April 29, 1965, although turtles were active prior to that time.

Since mating behavior was observed early in March and most males are in a testicular breeding condition by April, the early activity of *Chrysemys* seems related to reproduction. Adult *Chrysemys* apparently are reporductively active in early spring. This leads to increased movement when water temperatures reach a minimum tolerance level.

Sexton (1959a) found that by June 1 most _Chrysemys_ were associated with dense aquatic vegetation. This was also observed at Sherriff's Marsh. The increase in plant growth during May in conjunction with lowered water level provided many areas where aquatic plants were in heavy concentration. On June 9, 1966, 60 heads were counted in an area with heavy duckweed cover, whereas no turtles were seen in a nearby area with no surface vegetation. Dense aquatic vegetation functions as a means of physical support for the turtles as they carry out normal activities during the summer (Sexton 1959a).

A search for food is apparently initiated by some individuals before the end of the breeding season as indicated by the heavy capture in bait traps during late April and early May of 1965. The reduction in the number of turtles collected in bait traps in May was apparently due to the increase in aquatic vegetation and abundant food in the marsh.

Chrysemys entered Zone 5 in large numbers in late May and most departed by September. The association of _Chrysemys_ with this area in the summer appears to be dependent upon the surface vegetation which provides an ideal habitat in regard to support and abundant food. The hard bottom and shallow depth, however, are not suitable for the winter. Apparently, then, Zone 5 serves as a feeding ground in which turtles congregate in the summer.

The observation of large numbers of *Chrysemys* swimming in 4° C water is perhaps explainable as thermoregulatory behavior. The open water in April and clear ice in December afforded maximum light penetration and warming of the dark substrate. By exposing themselves on the substrate surface, the turtles were able to obtain the maximum heat gain possible under the conditions. The effectiveness of solar radiation in raising body temperatures of turtles in shallow water is not known, although other species have been reported basking underwater (Cagle 1944). Boyer (1965) suggests that increased light intensity and rising water temperatures motivate basking behavior which raises body temperature in turtles.

Terrestrial

Chrysemys were collected on land during four periods: late April and the first week in May; late May; June and early July; and September. The early spring migrations occurred during the mating season and primarily involved mature individuals. However, the presence of juveniles would appear to mar an otherwise satisfactory explanation that this activity results from reproductive activity (Cagle 1944a). This is not necessarily so in the present study since the immature turtles found on land were very close to maturity and could conveivably have already been under adult hormonal influence. Terrestrial movement early in the spring is possibly another expression of reproductive appetitive behavior.

All of the Chrysemys collected on land in early spring were directly between two proximate bodies of water. Turtles in Sexton's (1959a) population at this time of year were also traveling from one aquatic area to another. This indicates that terrestrial movement is not simply random wandering but is directed in that the turtle is trying to reach another body of water. Very few turtles were found on land in the vicinity of the marsh and in all instances these were between Zone 5 and Zone 15, the swampy area to the north. This small swamp represents the only area of Sherriff's Marsh which is isolated from the remainder. Perhaps the reason that turtles are seldom found on land around Sherriff's Marsh in the spring is because the different habitats are connected by water routes and new areas can be reached without terrestrial movement. In conclusion, travel of Chrysemys over land in the spring occurs only when such land lies between aquatic areas which are not connected by a water route.

A few turtles were collected on land in late May of 1965 and 1966. Two of these were mature females presumably seeking nesting sites. The others were three immature females and a mature male. A search for a more favorable habitat might be a possible explanation for this terrestrial travel, although data are not available to substantiate this supposition.

All of the *Chrysemys* found on land during June and July were mature females presumably making temporary excursions onto land for nesting purposes.

Terrestrial travel in the fall is widespread among turtles (Cahn 1937; Cagle 1944a; Carr 1952). These migrations have generally been attributed to movement to more suitable areas for hibernation. Further comment is not warranted on the basis of the present study except to point out that no turtles were seen on land around Sherriff's Marsh during this season, suggesting that, as with spring travels, *Chrysemys* travel across land only when a water route is not available.

The effect on the population, of *Chrysemys* entering, or leaving, the study area appears to be minimal. A statement that migrations to, or from, any unenclosed area does not occur can hardly be made. However, indirect evidence supports the view that the population of *Chrysemys* at Sherriff's Marsh is relatively uninfluenced by migration. Several factors warrant such a conclusion.

(1) More than 100 collecting trips to Sherriff's Marsh were made during the study. On many of these trips the roads encircling the marsh were traveled by car. The only turtles, dead or alive, were found on the road between Zones 5 and 15, two aquatic areas. Also, other than females laying eggs, no turtles were found on land around the marsh during the entire study.

(2) More than 1000 turtles were marked in Sherriff's Marsh. Almost 400 turtles were captured two miles away in Wintergreen Lake, the nearest sizable population of Chrysemys. None of these proved to be marked turtles from Sherriff's Marsh. Also, a large number (266) of Chrysemys from Wintergreen Lake were marked and released by Dr. M. M. Hensely in 1957. Although several of these were recaptured in Wintergreen Lake during the present study, none were seen in Sherriff's Marsh. There is no evidence of interchange between the Sherriff's Marsh and Wintergreen Lake populations.

Local Travel in Sherriff's Marsh

Several workers have investigated the home range of turtles. Terrapene carolina (Breder 1927; Nichols 1939a; Stickel 1950), Gopherus agassizi (Bogert 1937; Woodbury and Hardy 1948), and Trionyx ferox (Breckenridge 1955) have been shown to confine their activities to restricted areas. Cagle (1944a) studied home range and movement of Pseudemys and Chrysemys and concluded that they "live within selected areas" which "may include parts of two or more water bodies." Cagle states further that no territorial defensive behavior was observed. Pearse (1923a) considered Chrysemys in Lake Mendota to be "rather sedentary." Sexton (1959a) indicated that Chrysemys are restricted in their travel under conditions of little vegetation change, but that under "varying conditions" they often change their areas of activity. Homing abilities have been noted in Chrysemys (Cagle 1944a; Williams 1952) whereas Ortleb and Sexton (1964) investigated several cues which might be used in orientation.

Travel during a single summer was limited in most Chrysemys from Sherriff's Marsh (Table 14). This behavior may be attributed to the several areas of surface vegetation with which most of the turtles were associated. Such areas undoubtedly offer sufficient food and support, and there is little reason for turtles leaving such an area during the summer.

Over 40 percent of the recaptured mature females were found to have changed locations within the marsh during successive summers. The change of area possibly occurs during the egg laying season. A female seeking a nesting site leaves the water and walks until a suitable place is found. This may come about only after considerable random wandering and be several meters from water. The return trip to water is probably more direct and not necessarily to the area previously inhabited. Upon reaching the water the turtle seeks an area with surface vegetation and probably remains in the vicinity throughout the summer. Such travels would guarantee interchange among a population of otherwise sedentary animals. This could also result in the invasion of a new aquatic area if, after laying, the female entered another body of water. A female entering a previously uninhabited area would probably continue to lay fertile eggs, at least in the following year as is true with *Malaclemmys* (Hildebrand 1929). Such an effort would be adequate to establish a *Chrysemys* population within a few years.

Mature males showed little change of location between summers. This is particularly surprising in view of the high degree of travel in the spring time. One interpretation of this phenomenon may be that males have a "summer home range" to which the animal returns after long ventures during the breeding season. No explanation is readily available as to why males should return to former feeding areas, whereas, females do not. Sexton (1959a) indicated that adult *Chrysemys* tended to wander more than immature ones. This seemed true in regard to adult females at Sherriff's Marsh but not adult males. Most of the turtles from one to three years old were recaptured in the same places the following year. Large scale juvenils dispersal does not appear to be a primary means of invading new areas.

SUMMARY AND CONCLUSIONS

(1) A quantitative and descriptive analysis was made of the life cycle, population dynamics, and ecology of the painted turtle, *Chrysemys picta*, in two populations in southwestern Michigan.

(2) Maturity of *Chrysemys picta* is a function of size. Males in the study populations reach maturity at a plastron length of approximately 80 mm, females at approximately 115 mm.

(3) The male reproductive cycle is divisible into three seasonal phases. During the mating period from late March to early May the testes are small but the sperm ducts are enlarged and filled with sperm. Spermatogenesis occurs from July to October and results in an increase in the size of the testes which contain all of the sperm at this time. The winter phase is characterized by small testes with most of the sperm contained in the epididymis. Transitional periods occur between each of these phases. Courtship behavior occurs in the spring and fall but effective mating during the latter period is unlikely, due to the lack of sperm in the ducts at this time.

(4) Ovarian follicles begin to increase in size in September. By March, the largest follicles average 15 to

17 mm in diameter. Immediately prior to ovulation there is an increase to a diameter of approximately 18 mm. Ovulation occurs near the middle of May. Another group of enlarged follicles is invariably present after ovulation in May. These are presumably the follicles of a second clutch. The second ovulation probably occurs near the middle of June. The first clutch of eggs is laid in late May and early June, the second clutch in late June and early July. There is no indication of a third clutch. After the second ovulation the follicles do not increase in size until September. Clutch size is about 6.5 eggs. The annual reproductive potential for individual females is around 13 eggs per year.

(5) Growth rate, based on plastron length, is fastest during the first two years but is relatively similar throughout the juvenile stage. Growth decreases abruptly in both sexes when maturity is reached. Growth rate probably decreases to some degree as mature turtles grow older.

(6) An estimated 2328 individuals were in the marsh population. Of these, 1403 were immature. The mature animale were in a sex ratio of nearly 1:1.

(7) Less than 2 percent of the eggs laid each year in the study population develop into juveniles which successfully enter the population. Egg predation is a heavy source of mortality.

(8) Mortality is not consistently greater in any particular age class of immature turtles. Thus, once a hatchling has completed the first growing season there is a high probability that maturity will be reached.

(9) Upon reaching adulthood, both sexes experience abrupt increases in mortality rate. This is attributed to the combined effect of behavioral and physiological changes which accompany maturity thus making adults more susceptible to certain environmental hazards. Some manifestations of these changes are earlier vernal activity, greater terrestrial activity in some situations, and greater expenditure of energy for reproductive function. All of these factors tend to lessen the individual's chances of survival.

(10) The survivorship pattern of the study population is a combination of a Type IV survivorship curve (egg-Juvenile) and a Type III (adult). The former is characterized by an extremely high mortality rate initially followed by a low mortality rate. A population following a Type III curve has a constant mortality rate at all ages.

(11) Adult Chrysemys become active in early spring when water temperatures reach the minimum tolerance limits. Reproductive activity appears to be responsible for this early emergence. Juveniles are seldom seen before late May.

(12) The early spring activity is characterized by terrestrial movement in some areas where land separates proximate

bodies of water. Apparently the aquatic conditions preferred for winter quarters may be unsuitable for breeding purposes, thus explaining the frequent overland migrations. Such terrestrial travel is seldom observed in areas where different aquatic habitats are connected by water routes. Travel by males is greatly increased in the spring.

(13) By late May most Chrysemys are associated with areas of heavy vegetation. Local movement of most individuals is limited throughout the summer. Individual juveniles and mature males are usually found in the same general area in successive summers whereas mature females have often traveled. This is possibly a result of nesting females leaving the water from one area but returning to another. This would serve as an effective dispersal mechanism. Why males return to the same areas in successive summers after their springtime activity is unexplained.

(14) By September, the turtles begin to leave summer feeding areas which are unsuitable for winter. This again results in travel over land in some areas. The tolerance level to temperature during this period is less well defined than in the spring and responses of the population are more gradual. Activity at low temperatures in the fall is definitely reduced in adults. Juveniles remain active as long as adults in the fall.

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