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FOOD HABITS OF THE COPPERHEAD IN MIDDLE TENNESSEE

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ABSTRACT

The feeding habits of copperhead snakes in the Cumberland Plateau of Middle Tennessee were investigated. Digestive tracts from 77 snakes were examined. Mammals were the most important food consumed, particularly prairie voles and pine voles. Insects, primarily Lepidoptera larvae, were important also. Peaks in food intake occurred in June and August. Snakes collected in fields contained six times greater volume of food than snakes obtained in woodlands. Voles were the principal food of snakes in fields, while caterpillars ranked first in the diet of snakes taken in woodlands. Males fed mainly on voles and caterpillars, nongravid females ate white-footed mice, voles and birds, and gravid females used lizards and shrews as their principal foods.

INTRODUCTION

Comprehensive analyses of the diet of copperheads, *Agkistrodon contortrix*, were done by Fitch (1960) in Kansas, Clark (1949) in Louisiana, Surface (1906) in Pennsylvania, and Uhler, Cottam, and Clarke (1939) in Virginia. These studies indicated that the copperhead's diet was eccentric, varying in different geographical areas of its range. Ditmars (1936) suggested that the copperhead's diet may show seasonal variation, but no quantitative appraisal of this facet of the snake's dietary pattern was found in the literature.

The objective of this study was to describe the feeding habits of the copperhead in the Cumberland Plateau area of Middle Tennessee. The snake's dietary pattern was analyzed to ascertain qualitative and quantitative changes in its diet throughout its activity period, and to detect differences between feeding patterns of male and female copperheads. An attempt was made to relate feeding activity to environmental temperature and to factors associated with reproduction.

THE STUDY AREA

Copperheads utilized in this study were collected on the Cumberland Plateau. A majority (67.5 percent) of the snakes were collected on the Catoosa Wildlife Management Area in Cumberland County, and the remainder were obtained from areas ecologically quite similar to the Catoosa area. This area is 1800 to 2000 feet above sea level. Typically the topography is level to gently rolling. Two major streams, the Obed River and Daddy's Creek, occur on the Catoosa Wildlife Management Area. Sandstone, shale, and limestone outcroppings are exposed on the slopes of these streams and their numerous small tributaries. The Catoosa area is predominantly forested with oaks *(Quercus rubra* L., *Q. falcata* Michx., *Q. stellata* Michx.), Virginia pine *(Pinus virginiana* Mill.), and sourwood *(Oxydendrum arboreum* L.) in the dry uplands; hickory, maple and beech are common. Numerous open fields are scattered throughout the Catoosa Wildlife Management Area. Most of these fields are kept in early stages of succession by game management activities. The climate of Cumberland County is temperate and continental, with moderate winters and mild summers. Summer temperatures rarely exceed 90 F. Annual precipitation averages 54.19 inches and is distributed rather evenly throughout the year (Hubbard, et al. 1950).

METHODS

In 1966 digestive tracts from 77 snakes were collected: April (1), May (7), June (13), July (23), August (15), September (17) and October (1). Sixty-five contained some food material, with 19 of these having a recently ingested meal. Specimens were collected by searching (turning rocks and logs) fields and woodlands, and by driving and searching roads after dark. Several specimens, killed by mowing machines, were donated by personnel of the Catoosa Wildlife Management Area. A few snakes were brought to the laboratory by other interested individuals. Live snakes were killed immediately and the digestive tracts removed and preserved. The digestive tracts were opened their entire length, food items were removed and identified, and volumes were determined by water displacement. Importance values were assigned each type of food item. The importance value is the sum of the relative number, relative frequency, and relative volume, divided by three to reduce the value to a proportion of 100 (see footnote, Table I.)

RESULTS

Mammals were the most important class of food consumed by copperheads in Middle Tennessee and ranked high in the diet each month (Table 1 and Fig. 1). Five species of mammals were utilized, with prairie voles *(Microtus ochrogaster)* and pine voles *(M. pinetorum)* ranking first and second in importance in the

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Table I. Prey utilized by Copperheads, April-October, 1966, in Middle Tennessee.

Food Item	Total Number	Relative Number[1]	Relative Frequency[2]	Relative Volume[3]	Importance Value[4]
Mammalia					
Cricetidae					
Microtus ochrogaster	18	17.8	19.2	40.7	25.9
M. pinetorum	11	10.9	11.0	23.8	15.2
M. sp.	1	1.0	1.4	0.4	0.9
Peromyscus sp.	9	8.9	12.3	3.9	8.4
Soricidae					
Blarina brevicauda	6	6.0	8.2	3.3	5.9
Crypototis parva	1	1.0	1.4	0.4	0.9
Unidentified	2	2.0	5.5	3.1	4.2
sub total	52	51.6	61.7	75.8	63.0
Insecta					
Lepidoptera larvae					
Automeris io	20	19.7	9.5	7.6	12.3
Citheronia regalis	2	1.9	2.7	1.9	2.2
Unidentified	11	10.8	8.2	1.9	5.9
Cicadidae					
Unidentified	2	2.0	1.4	0.8	1.4
sub-total	35	34.4	21.7	12.1	22.8
Aves (unidentified)	4	4.0	2.7	10.8	5.9
sub-total	4	4.0	2.7	10.8	5.9
Reptilia					
Lacertilia					
Sceloporus undulatus	3	3.0	4.1	0.8	2.6
Unidentified	1	1.0	1.4	0.2	0.9
Serpentes					
Unidentified	1	1.0	1.4	Tr.	0.8
sub-total	5	5.0	6.9	1.0	4.3
Unidentified	5	5.0	6.9	0.2	4.0
sub-total	5	5.0	6.9	0.2	4.0
Totals	101	100.0	100.0	100.0	100.0

1. Number of individuals of one food item as a % of the total number of all items.
2. Number of occurrences of one food item as a % of the total number of occurrences of all items.
3. Volume of one food item as a % of total volume of all items.
4. Sum of relative number, relative frequency and relative volume 3.

Table II. Food intake per month by copperheads in Middle Tennessee.

Month	No. snakes	Mean volume (cc.)	Mean monthly temperature (1966)
April	1	tr.	56.2 F.
May	7	3.3	62.7
June	13	20.1	70.4
July	23	3.4	76.8
August	15	7.4	72.9
September	17	2.2	66.7
October	1	0.0	54.7
Totals	77	6.6	

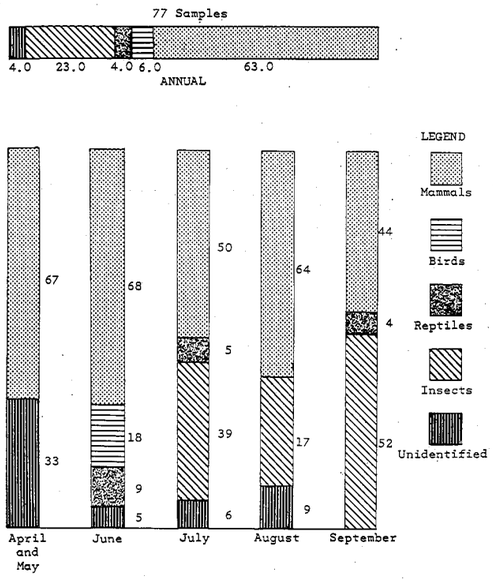

Fig. 1. Monthly dietary patterns, by importance value, of copperheads in Middle Tennessee.

diet. White-footed mice of the genus *Peromyscus* also were important constituents in the copperhead's diet in Middle Tennessee. Identification to species of these mice was not possible, but *P. leucopus* is common on the Cumberland Plateau, and it is probable that this species was the principal one utilized by copperheads on the study area.

Insects, particularly Lepidoptera larvae were important prey also. Larvae of the io moth *(Automeris io)* ranked third in the diet; of 35 insects eaten by snakes in this sample, 20 were larvae of the io moth (Table I). Reptiles and birds occurred sporadically in the diet, but were not important prey items in the diet of copperheads on the Cumberland Plateau.

Food intake, measured as mean volume per snake, varied widely between months (Table II). Peaks occurred in June and August, with a sharp decline in July, suggesting that copperheads feed irregularly. Copperheads were relatively active in September, but fed little during this period.

Food habits of 42 snakes taken from woodlands were compared with those of 17 taken from open fields. Food is apparently more abundant and/or more readily obtained in fields than in woodlands, for snakes collected in fields contained an average volume of food six times greater than the average volume for snakes in woodlands. Voles were the principal food of snakes from fields, while caterpillars were the most important species eaten by snakes from woodlands (Table III).

The dietary patterns of three subgroups within the population were analyzed (Table IV). The subgroups, delineated on the basis of sex and reproductive status of the individuals, included 50 males, 12 gravid females, and 13 non-gravid females. Twenty-eight percent of the males were collected from fields. Voles were the most important items in the diets of males, probably reflecting this sampling distribution (Table IV). Non-gravid females occurred in open fields in about the same proportion as did the males. However, their dietary pattern was dissimilar to that of the males. White-footed mice, shrews, and birds were significantly more important prey species for these females than for males. All gravid females in this study were collected in wooded areas. Their diet differed markedly from the other subgroups, with lizards and shrews ranking first and second, respectively. The diet of gravid females

Table III. Comparison of foods utilized by copperheads in two major habitat types in Middle Tennessee.

Food	Importance Value[1] Woodland Habitat	Field Habitat
Mammals		
voles	15.2	70.6
mice	14.2	2.9
shrews	13.3	6.1
unidentified	3.4	3.9
Insects		
caterpillars	42.8	---
cicadas	2.9	---
Birds (unidentified)	---	13.6
Reptiles		
lizards	3.7	---
snakes	1.3	---
Unidentified	3.2	2.9
Totals	100.0	100.0

[1] Refer to Table 1.

Table IV. Comparison of the food habits of three subgroups of copperheads during June, July and August, 1966, in Middle Tennessee.

Food	Importance Values[1] Males	Non-gravid females	Gravid females
Mammals			
voles	53.2	24.4	---
mice	4.4	24.6	---
shrews	4.8	12.2	42.9
unidentified	4.5	---	---
Insects			
caterpillars	25.3	5.8	9.5
cicadas	2.3	---	---
Birds			
unidentified	1.5	27.9	---
Reptiles			
lizards	---	5.1	47.6
snakes	0.6	---	---
Unidentified	3.4	---	---
Totals	100.0	100.0	100.0

[1] Refer to Table 1. for explanation of this term.

differed from non-gravid females and males in the quantity of food consumed as well as in quality. Five of 12 gravid females collected in June, July, and August had empty digestive tracts. Twenty-five of 26 males and all 11 non-gravid females collected during this same period contained some food. Those gravid females which had fed contained very small volumes of food compared to other copperheads.

Discussion

The high incidence of mammals (particularly microtine rodents) and their relative importance in the diet of copperheads is substantiated by studies of the foods of copperheads throughout the species' range. Meadow voles *(Microtus pennsylvanicus)* and other microtine rodents were the most important foods of copperheads in Pennsylvania (Surface 1906). In Kansas the prairie vole was the main food of copperheads (Fitch 1960). Uhler, et al. (1939) reported voles, including meadow voles, pine voles, red-backed voles *(Clethrionomys gapperi),* and southern bog lemmings *(Synaptomys cooperi),* were the principal mammalian foods of 105 copperheads in Virginia. The vole's habit of traveling in the confines of surface or subsurface runways may increase their vulnerability to copperhead predation. In fields of dense grass these runways offer avenues of free movement to copperheads, and their regular use by voles may leave scent that attracts the snakes.

The importance of other types of food for copperheads varies regionally. Shrews, moderately important to copperheads in Tennessee, were a staple prey item in Virginia (Uhler, *et al.* 1939), but were seldom eaten in Pennsylvania (Surface 1906). Fitch (1960) stated that shrews were particularly important prey of young copperheads in Kansas. Insect larvae (mostly Lepidoptera) were heavily utilized by copperheads in Pennsylvania (Surface 1906), Virginia (Uhler *et al.* 1939), and on the Cumberland Plateau, but ranked low in Kansas (Fitch 1960). Cicadas, little utilized in Tennessee, were the insects most frequently eaten by copperheads in Kansas (Fitch 1960). Surface (1906) also reported that cicadas were important food for copperheads, noting that some snakes were gorged with these insects. Reptiles, particularly ring-necked snakes *(Diadophis punctatus)* and skinks *(Eumeces fasciatus),* formed a significant portion of the diet of young copperheads in Kansas (Fitch 1960). Lizards and turtles were important foods in a sample of 13 copperheads from Georgia (Hamilton and Pollack 1955), while elsewhere reptiles ranked low (Uhler, *et al.* 1939; Surface 1906). Ring-necked snakes and other small snakes frequently occurred in close association with copperheads on the Cumberland Plateau, but were infrequently used as prey. Only one juvenile copperhead was examined in this study, which may partially explain the low importance value of reptiles. Amphibians, not utilized as a food source by copperheads on the Cumberland Plateau, comprise a substantial portion of the copperhead's diet in some areas. In Louisiana, Ranid frogs were the most important food in a sample of 55 copperheads (Clark 1949), and salamanders were important foods of copperheads in Virginia (Uhler, *et al.* 1939). The low use of amphibians in Tennessee does not reflect the abundance or availability of these potential prey species in the copperhead's environment, for on several occasions copperheads were captured at night in close association with an abundance of frogs and toads.

A decline in feeding activity in July, observed as a decrease in mean volume of food per snake, possibly was related to unfavorably high temperature which occurred during that month. Snakes frequently reduce their activity during periods of unfavorably high ambient temperature, and thus are less likely to search for or encounter prey under these conditions. Copperheads were relatively active in September, however, another period of low feeding activity. The mobility of snakes during this time probably was, as noted by Fitch (1960), associated with a return to hibernacula rather than with food-gathering.

Differences in food habits of snakes from woodland habitats compared with those from field habitats primarily reflected differences in availability of prey species. Voles, particularly prairie voles, are common in fields on the study area but are rare in woodlands. Conversely, caterpillars of the type consumed by the snakes were more abundant in woodlands than in fields. However, the high use of voles in several studies of copperheads indicates a decided preference for this group of animals, and perhaps the use of other foods in certain environments, such as white-footed mice, shrews and caterpillars, is best explained as a necessary

substitution for the preferred voles where they are less available.

Differences in the feeding patterns of subgroups of snakes differentiated according to reproductive status is partially an expression of differences in their total behavior pattern, including habitat selection. For example, all gravid females in this study were collected in wooded areas. Their diet, principally lizards and shrews, partly reflected the available species in this habitat, but also resulted from the snakes' behavior patterns. Fitch (1960) noted that while other snakes disperse from the woodland hibernacula in the spring and return in the fall, gravid females tend to remain near the hibernacula all summer. He also observed that females tend to bask more frequently than other subgroups, and sometimes occur in loose aggregations of several individuals. These behavior traits suggest that gravid females may be less active than other copperheads. Lizards and shrews are relatively active animals, and perhaps their movements brought them in contact with gravid females, thus increasing their availability to this less active subgroup of snakes. Klimstra (1959) observed a similar relationship between reproductive status and feeding activity in the cottonmouth *(Agkistrodon piscivorous)* in Southern Illinois. He reported that 63 percent of the empty digestive tracts collected in July, August and September were from females, and 62 percent of these females were gravid.

Conclusions

The copperhead snake is characterized by a wide adaptability in its prey selection over the species' range. The composition of the diet varies between populations, and between seasons within a population. However, mammals, particularly voles, assume a paramount role in the diet in most populations and probably can be regarded as the basic class of food for this snake.

The abundance and availability of prey influences the diet markedly. In some instances, however, prey which is abundant and available, and which is acceptable to copperheads in some populations, is rejected in others. In this study, copperheads refused abundant amphibians, while in other places they accepted them readily.

Gravid females are less mobile than non-gravid females and males, feed less than those snakes, and restrict their movements to wooded areas. These traits produce a diet which differs quantitatively and qualitatively from the other groups. The presence of young in the reproductive tract apparently influences the female to live a more sluggish, sedentary life, and places no excessive strain on the energy and nutritional balance of these gravid females.

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RADIATION-INDUCED ANATOMICAL MODIFICATIONS IN FOREST TREES

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Abstract

Aberrant stem and foilage samples were collected from several forest tree species irradiated by fast neutron or ^{60}Co gamma sources. Common gross morphological abnormalities such as fused stems, alterations of size and shape of leaves and necrosis in meristematic regions were examined microscopically.

These frequently-reported changes in plant growth habit were described by effect of radiation on internal structure. Probable effects of these tissue changes on the physiological function of organs are discussed. Of particular significance were anomalies in vascular tissues of foilage which could effect the transport of both mineral and food substances.

Introduction

Modifications of growth and development of organs of higher plants may be induced by exposure to appropriate doses of ionizing radiation. These modifications are due to damage to cytological, genetical or physiological processes in cells and tissues. These responses have been reported previously for many higher plants exposed to X-rays (Johnson 1936), gamma-rays (Gunckel, *et al.* 1953; Gunckel and Sparrow 1954), and fast neutrons (Witherspoon 1965). Moreover several review articles have treated this subject, particularly in the case of gamma radiation (Sparrow and Pond 1956, Gunckel 1957, Gunckel and Sparrow 1961) in some detail. Morphological effects of irradiation in plants were summarized by Gunckel and Sparrow (1961) who also discussed the variables affecting structural responses.

There is little specific information about physiological or metabolic disturbances in plants which have undergone changes in organ structure. How functionally efficient, for example, are the thickened, chlorotic leaves resulting from irradiation of buds? Certainly an assessment of the ecological effects of ionizing radiation would be influenced by the ability of aberrant plant organs to manufacture and transport necessary materials.

Anatomical analyses of foilage and stem abnormalities should offer leads to likely functional significances of these radiation-induced structural changes. This report describes some of the abnormal organ structures in irradiated forest tree species; Virginia pine *(Pinus virginiana* Mill), sassafras *(Sassafras albidum* Nutt.), *Sequoia gigantea*, ash *(Fraxinus* sp.), sumac *(Rhus* sp.), dogwood *(Cornus florida* L.), persimmon *(Diospyros virginiaia* L.), red maple *(Acer rubrum* L.), tuliptree *(Liriodendron tulipifera* L.); emphasizing anatomical changes that may be functional.

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Materials and Methods

Since initial operations in 1963 of the unshielded Health Physics Research Reactor at Oak Ridge National Laboratory, portions of contiguous forest have been exposed to discontinuous, low-level, fast neutron radiation. Studies on the effects of this radiation in terms of mortality, growth and gross morphological changes have been reported (Witherspoon 1965). Additional laboratory studies (Witherspoon 1967), on radiosensitivity of forest tree species to acute radiation exposures have been performed. In both field and laboratory studies irradiated plant materials were collected for routine microscopic examination. Major structural abnormalities in foilage and wood of tree species have been cataloged according to type of radiation, mode of radiation delivery and dose.

Preparation of tissues for anatomical study followed standard botanical techniques. Shoot apices and leaf materials were killed and fixed in Craf III, dehydrated and infiltrated with a standard tertiarybutyl alcohol series and embedded in Paraplast. Woody material was killed and fixed in FAA. Sections were cut 10 to 25 microns thick and stained with safranin and fast green.

Results and Discussion

Meristems. The relative radiosensitivity of meristems was recognized early, and reasons for their radiosensitivity were reviewed by Gunckel (1957) and Sax and Schairer (1963). Loss of apical dominance after chronic irradiation with X or gamma-rays has been frequently observed in both gymosperms and angiosperms (Sax and Schairer 1963); less frequently after chronic fast neutron irradiation (Witherspoon 1965).

Differential radiosensitivity of zones within shoot meristems have been described by Pratt *et al.* (1959) for angiosperms, and by Miksche *et al.* (1962) for yew. After exposure to ionizing radiation, both inhibition of mitotic processes and induced physiological changes may be manifested in stem mortality or stem growth inhibition.

Apical meristems of leader shoots of Virginia pine *(Pinus virginiana* Mill) were exposed to lethal, acute doses of fast neutron radiation (100 and 300 rads), and were collected two weeks later. Damage is described using the zonal termnology of Sacher (1954).