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Age determination and population characteristics of red foxes from Maryland[1]

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Abstract

Between 1976 and 1979, 210 red foxes *(Vulpes vulpes)* were collected throughout Maryland to determine the age of each fox based on eye lens weights, epiphyseal closure of the humerus, baculum weight, tooth cementum annuli and skull measurements. Approximately 50 % of the red foxes collected during the trapping season (October–January) were juveniles; 20 % were one year olds; 16 % were 2-year olds; 8 % were 3-year olds; and 4 % were 4-years old or older. An ovulation rate of 6.0 was calculated from the number of corpora lutea per parous female. A mean litter size of 5.0 was determined from the mean number of placental scars per parous female. The peak of the breeding takes place in mid-January. Sixty-seven percent of the adult males produced sperm in October. Ninety percent of the adult males were producing sperm in November compared to 47 % of the juveniles. To assess the physical condition of each fox an adrenal index, spleen index, and body fat index were developed. Adrenal and spleen indices indicated that 5-year olds may be subjected to more stress than

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younger age classes. Body fat indices showed a significant increase from fall to winter suggesting that red foxes are in their best condition during the peak of the breeding season. Ten foxes were infected with mange and significant variation was found between adrenal indices for absent and severe cases of mange.

Introduction

During the 1970's there were significant increases in fox harvest, fox pelt value, and decreases in habitat throughout North America. This is a land-wildlife problem that should be addressed by North American wildlife ecologists.

Maryland (USA) fur harvest records clearly show an increased interest in red fox as a furbearer. During the 1970–1971 trapping season an estimated 362 red foxes were trapped in Maryland. This number steadily increased to a peak of 4,620 during the 1975–1976 season (Deems and Pursley 1978). The 1976–1977 and 1977–1978 seasons showed a decline from the 1975–1976 high with catches of 3,928 and 4,318 red foxes, respectively. In 1978 the average pelt value climbed to $ 62, representing a total revenue to Maryland trappers of $ 267,716. Estimates of the 1978–1979 harvest indicated the number of red foxes trapped in Maryland approached 5,000 (Maryland Department of Natural Resources 1979 Fur Harvest Records, Unpublished). The increase in the number of red foxes trapped may be explained partly by the increase in the number of trappers in Maryland. For example, between 1975 and 1979 the number of Maryland Fur Trapper's Association district clubs alone increased from 2 to 6.

Additionally, red fox habitat is declining in Maryland as new housing projects continue to reduce the amount of farm land. In 1968 there were 19,700 farms in Maryland comprising 1,296,000 hectares. By 1977 Maryland had 17,500 farms totaling 1,183,000 hectares, which represented a loss 113,000 hectares of farm land (Maryland Department of Economic and Community Development 1977).

With harvest levels increasing and suitable habitat decreasing, the Maryland Department of Natural Resources recognized the need to effectively manage this valuable furbearer. In 1978 the red fox was reclassified from a predator to game animal. This action allowed the Maryland Department of Natural Resources to post its first open season on red foxes (November 1, 1978 to January 8, 1979). Two important implications of this action were (1) pregnant females would be protected, increasing pup production; and (2) pups would be protected from indiscriminate shooting while still at the den site.

However, the only source of information on the red fox in Maryland was from annual fur harvest records. These records are inadequate for obtaining the biological information necessary to effectively manage the red fox as a fur resource. In this study reproductive parameters, age structure and physical condition of the Maryland red fox population are assessed.

Study area

The area of collection was broken down into 5 regions as shown in Fig. 1 (p. 298).

Region 1

Garrett County, the western most county of Maryland, was designated as Region 1. Part of the Allegheny Plateau of the Appalachian Mountain Range, this region consists of several mountains over 900 meters above sea level. The highest point is Backbone Mountain which is 1,024 meters above sea level. Bedrock underlying this region consists of gray and red sandstone, acid and calcareous shale, chert, and limestone. Soils are characterized as rocky, shallow, and acidic. Average annual temperature ranges from 9 °C to 10 °C (Miller 1976). Hardwoods such as sugar maple *(Acer saccharum)*, red oak *(Quercus rubra)*, beech *(Gagus grandifolia)* and yellow birch *(Betula alleghaniensis)* are the dominant forest species.

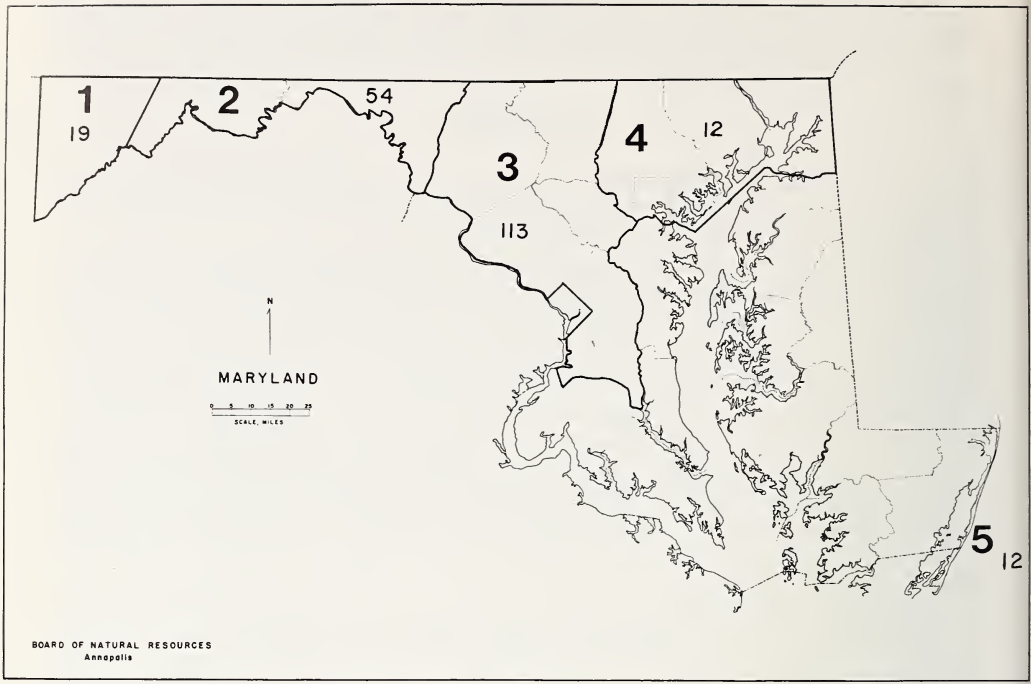

Fig. 1. The 5-regions of Maryland from which red foxes were collected (1976–1979). Numbers indicate sample sizes

Region 2

Region 2 consists of Allegany and Washington Counties within the Ridge and Valley province of Maryland. Soils are variable, dominated by medium and moderately coarse textured soils on residuum of acid shale and sandstone. Average annual temperature is about 12 °C. Oaks (*Quercus* sp.) pines (*Pinus* sp.), and hickories (*Carya* sp.) characterize the forests of this region (Miller 1976).

Region 3

Region 3 is comprised of Frederick, Carroll, Howard, Montgomery, and Prince Georges counties. Situated between the Blue Ridge and the Coastal Plain, this region is called the Piedmont Region. Rolling hills and stream valleys are characteristic of this area. Soils are medium textured on residuum of acid and basic igneous rocks and metamorphic rocks. Average annual temperature fluctuates around 12 °C (Miller 1976).

Region 4

Region 4 consists of Baltimore, Harford, and Cecil Counties. Although the soils and rock strata are similar to Region 3, this area was considered separately for several reasons. Trappers were not organized into a district club in this area until the second year of this study. Consequently, foxes were collected from this region for 1-year only. All 3 counties in this region border the Chesapeake Bay and contain areas of sandy and silty soils, characteristic of the coastal plain. Average annual temperature is 12 °C (Miller 1976).

Region 5

Assateague Island is designated as Region 5. Tidal marshes, sand dunes, and coastal beaches are characteristic of this island. Twelve red foxes were collected on this island the first year of the study. Average annual temperature ranges from 13° to 15 °C (Miller 1976).

Materials and methods

Red foxes were collected in Maryland counties west of the Chesapeake Bay and on Assateague Island on Maryland's eastern shore. Red foxes were not collected from eastern shore counties because: 1. eastern shore trappers were not organized into district clubs with regular monthly meetings, making it difficult to solicite their assistance in collecting foxes, and 2. eastern shore trappers concentrate their trapping effort on muskrats *(Ondatra zibethicus)*, nutria *(Myocastor coypus)*, and raccoons *(Procyon lotor)*.

Red foxes were collected by trapping, shooting, and road kills. However, the majority of foxes were collected from Maryland trappers during the trapping season. Eye lenses were removed from freshly killed foxes and placed in buffered formalin before the carcasses were frozen (Harris 1978).

Each fox was weighed in grams. Total length, tail length, hind foot length, and ear length were recorded in millimeters. The spleen, kidneys, liver, heart, and adrenals were weighed to the nearest 0.001 gram on a top loading Mettler Balance (Model P163).

Reproduction

Uterine horn length was measured in millimeters from the junction of the two horns to the ovary. Each horn was flushed with distilled water and was examined for sperm under a microscope. The number of placental scars or fetuses was recorded. Ovaries were detached and fixed in Bouin's fluid and later dehydrated in a series of alcohols. Using a microtome, the ovaries were sectioned 10 microns thick. The ovaries were stained, permanently mounted on slides and examined microscopically for corpora lutea.

The epididymus was separated from the testes and then both were weighed on a Mettler Balance. Each testis and epididymus was examined microscopically for sperm. The weight of the testis was used to calculate a testes index. Total body length was divided into the total weight of both testes to adjust for body size. The formula for calculating the testes index was:

$$TI = \frac{RTWT + LTWT}{TL} \times 10^3$$

where TI = testes index; RTWT = right testis weight; LTWT = left testis weight; TL = total length.

Age determination

The right humerus and skull were removed from each fox and placed in boiling water until the muscle tissue could be separated easily from the bone. The proximal epiphysis of the humerus was examined to determine the degree of ossification. Each skull was placed in bleach for 1-minute, then rinsed with water and allowed to air dry overnight. Skull measurements were taken using dial callipers.

Baculums were boiled until the muscle tissue could be removed easily from the bone. Each baculum was measured to the nearest 0.01 millimeter using a dial calliper, and weighed dry on a Mettler Balance.

Eye lenses were placed in a drying oven at 70 °C for 4 days, then weighed on a FPE precision balance to within ± 0.2 milligram.

A canine and premolar from each fox were removed and placed in decalcifying solution (3 % nitric acid) for 48 hours, or until the teeth could be cut easily with a scalpel. Teeth were rinsed in water and then sliced 15 to 20 microns thick on a freezing microtome, and immediately stained using a procedure similar to that of Grue and Jensen (1973) and Harris (1978). Cementum rings were counted and recorded immediately after staining.

Mortality

A life table was constructed using a format similar to that of Harris (1977) and Storm et al. (1976) and described by Caughley (1966, 1967).

The number of female live births per female was calculated by dividing the mean number of placental scars by 2 for each age class. The number of vixens alive at the start of each age class was calculated by dividing the adjusted frequency of age class, χ, by the adjusted frequency of juveniles multiplied by 1,000. The number dying during each age class was calculated by subtracting the 1χ values between 2 successive age classes (Caughley 1967). Since data were available for 2 successive years, mortality rates were calculated by substracting the second year frequency, $\chi + 1$, from the first year frequency, χ, and dividing by the first year frequency. In other words, the number of 1-year olds alive the second year came from the population of juveniles the first year. Therefore, the difference between the 2 frequencies divided by the number of juveniles gives the mortality rate for juveniles (Caughley 1967).

Physiological responses

The weight of the adrenal glands was used to calculate an adrenal index (AI) similar to that used by CHAPMAN et al. (1977). Total length was used to adjust for body size instead of total weight in order to eliminate variability associated with body weight. This index also allowed the use of foxes which had been pelted. The formula for calculating the adrenal index was:

$$AI = \frac{\text{Right Adrenal Wt.} + \text{Left Adrenal Wt.}}{\text{Total Length}} \times 10^4$$

Spleen weight was also used to measure physical condition (WILLNER et al. 1979). The formula for calculating the spleen index, SI, was:

$$SI = \frac{\text{Spleen Weight}}{\text{Total Length}} x\, 10^2$$

A body fat index was used to determine the condition of each fox. This index developed by RINEY (1955) and modified by CHAPMAN et al. (1977) provided a value from 1 to 4: 1 indicated no body fat present, 2 indicated a small amount of fat around the kidneys, 3 indicated fat covering more than one-third of the kidneys and adrenal glands and 4 indicated fat covering more than half of the kidneys and fat present in the mesentaries and throughout the body cavity.

Statistical analysis

Statistical tests used to analyze the classification variants were one-way and two-way analysis of variance, Duncan's New Multiple Range Test, and Spearman's Rank Correlation. Statistical tests were considered significant when $P < 0.05$ and highly significant when $P < 0.01$. Statistical abbreviations and table formats are similar to those by STEEL and TORRIE (1960).

Results and discussion

Collection of red foxes

Between December 1976 and January 1979, 210 red foxes were collected throughout Maryland. The largest number of foxes was collected in Region 3 where trapper cooperation was highest (Fig. 1). Ninety-four red foxes were collected during November and 65 during December. No foxes were collected in February and May.

Morphology

Whole weight, pelted weight, and body measurements were recorded for each sex and age class. Pelted weight was the only variable that showed a significant difference between age classes for both males and females (Table 1). Heart weight showed a significant difference between juveniles and adults ($P < 0.01$). Both adrenal ($P < 0.01$) and kidney weights ($P < 0.01$) showed significant differences between juveniles and adults.

A significant difference was found between the ovary weights of juveniles and adults and the uterine horn lengths of the two age classes (Table 2). There was no significant difference between testis weights of juveniles and adults, but epididymus weights were significantly different between the age classes (Table 3).

Many of the red foxes obtained from trappers already had been pelted. Therefore, pelted weights were used when whole weights were not available. Although juvenile and adult age classes could be separated on the basis of both whole weight and pelted weight, there is a considerable overlap in ranges and 95 % confidence intervals in both groups. According to STORM et al. (1976) juvenile red foxes are similar in size to adults by October, which may explain the overlap in ranges. The mean whole weight of adult male red foxes collected in Maryland was 4,483 grams and 3,645 grams for adult females. This compares to 5,250 grams for adult males and 4,128 grams for adult females collected in Illinois and 4,822

Table 1

Analysis of variance of whole weight (g), pelted weight and body measurements (mm) for sex and age of red foxes collected in Maryland (1976–1979)

Group	N	Mean	S.D.	S.E.	Min.	Max.	95 % Confidence Interval For Mean	Significance
Whole Weight								
Male								
Juvenile	7	3763.86	768.47	290.45	2595.0	4620.0	3053.1 to 4474.6	$p < 0.05$
Adult	9	4482.89	443.07	147.69	3838.0	4212.0	4142.3 to 4836.2	
Female								
Juvenile	11	3430.45	531.53	160.26	2570.0	4290.0	3073.4 to 3787.5	NS
Adult	3	3644.67	1042.70	602.01	2489.0	4515.0	1054 to 6234.0	
Pelted Weight								
Male								
Juvenile	64	3984.64	562.24	70.28	2005.0	5675.0	3844.2 to 4125.1	$p < 0.01$
Adult	40	4352.58	697.59	110.30	3135.0	6501.0	4129.5 to 4575.7	
Female								
Juvenile	41	3414.73	497.73	77.73	2230.0	4485.0	3257.6 to 3571.8	NS
Adult	44	3610.50	405.35	61.11	2710.0	4340.0	3487.3 to 3733.7	
Total Length								
Male								
Juvenile	63	978.17	36.94	4.65	881.0	1064.0	968.9 to 987.6	NS
Adult	42	978.42	45.57	7.03	859.0	1086.0	964.4 to 992.6	
Female								
Juvenile	44	927.34	45.17	6.81	840.0	1031.0	913.6 to 941.1	NS
Adult	39	941.49	38.66	6.19	832.0	1012.0	928.9 to 954.0	
Tail Length								
Male								
Juvenile	65	375.40	27.65	3.43	245.0	427.0	368.5 to 382.2	NS
Adult	42	381.19	30.53	4.71	330.0	515.0	371.7 to 390.7	
Female								
Juvenile	44	358.19	24.13	3.64	295.0	402.0	351.0 to 365.7	NS
Adult	39	362.46	18.87	3.02	317.0	407.0	356.3 to 368.6	
Hind Foot Length								
Male								
Juvenile	60	159.90	8.23	1.06	135.0	173.0	157.7 to 162.0	NS
Adult	41	159.31	11.25	1.76	106.0	173.0	155.8 to 162.8	
Female								
Juvenile	41	153.24	6.67	1.04	137.0	168.0	151.1 to 155.3	NS
Adult	39	155.69	6.86	1.09	133.0	167.0	153.5 to 157.0	
Ear Length								
Male								
Juvenile	6	84.33	6.43	2.62	75.0	92.0	77.5 to 91.0	NS
Adult	6	86.00	3.34	1.37	81.0	90.0	82.5 to 89.5	
Female								
Juvenile	5	87.60	1.52	0.68	86.0	90.0	85.7 to 89.5	NS
Adult	2	83.50	6.36	4.50	79.0	88.0	26.3 to 140.7	

grams for adult males and 3,938 grams for adult females collected in Iowa (Storm et al. 1976). In Indiana, Hoffman and Kirkpatrick (1954) reported the mean weight of male foxes as 5,253 grams and females 4,213 grams.

Data on liver, heart, spleen and kidney weights for red foxes are lacking in the literature. Although both heart and kidney weights show a significant difference between juveniles and adults, the overlap between individual juvenile and adult organ weights indicates that no single weight is reliable for differentiating between juveniles and adults.

Table 2

Analysis of variance of ovary weight and uterine horn length by age of red foxes collected in Maryland (1976–1979)

Group	N	Mean	S.D.	S.E.	Min.	Max.	95 % Confidence Interval For Mean	Significance
Right Ovary Weight								
Juvenile	43	0.210	0.110	0.017	0.076	0.739	0.177 to 0.244	NS
Adult	44	0.248	0.135	0.020	0.129	0.902	0.207 to 0.289	
Left Ovary Weight								
Juvenile	42	0.205	0.070	0.011	0.080	0.410	0.183 to 0.226	$p < 0.05$
Adult	44	0.269	0.166	0.025	0.150	0.998	0.218 to 0.319	
Right Uterine Horn Length								
Juvenile	40	96.42	12.94	2.046	72.0	135.0	92.29 to 100.56	$p < 0.01$
Adult	43	115.35	22.30	3.401	90.0	182.0	108.48 to 122.21	
Left Uterine Horn Length								
Juvenile	40	94.74	12.73	2.010	70.0	129.0	90.68 to 98.82	$p < 0.01$
Adult	43	114.67	22.14	3.376	85.0	201.0	107.86 to 121.49	

Adrenal weights of Maryland red foxes range from a low of 0.045 grams in juveniles to a high of 0.500 grams in adults. HOFFMAN and KIRKPATRICK (1954) reported heavier adrenals for Indiana red foxes (0.270 to 1.455 grams). They also reported high ovary weights (0.315 to 2.430 grams) and testis weights (2.9 to 15.5 grams).

LAYNE and MCKEON (1956) found that the uterine horns of juveniles are usually shorter and narrower than adult foxes. This study also shows a significant difference between the uterine horn lengths of juveniles and adults.

Table 3

Analysis of variance of testes and epididymides weights by age of red foxes collected in Maryland (1976–1979)

Group	N	Mean	S.D.	S.E.	Min.	Max.	95 % Confidence Interval For Mean	Significance
Right Testis Weight								
Juvenile	34	2.535	1.403	0.241	0.224	5.745	2.046 to 3.025	NS
Adult	24	3.010	1.330	0.271	0.444	5.569	2.449 to 3.572	
Left Testis Weight								
Juvenile	34	2.548	1.383	0.233	0.214	5.302	2.066 to 3.031	NS
Adult	23	3.088	1.475	0.307	0.492	6.332	2.450 to 3.726	
Right Epididymus Weight								
Juvenile	34	0.676	0.268	0.046	0.100	1.202	0.523 to 0.769	$p < 0.05$
Adult	23	0.826	0.242	0.050	0.400	1.222	0.722 to 0.031	
Left Epididymus Weight								
Juvenile	34	0.690	0.275	0.047	0.111	1.150	0.594 to 0.786	$p < 0.05$
Adult	22	0.847	0.250	0.053	0.464	1.292	0.736 to 0.958	

Reproduction

Only 4 of 96 female red foxes had ovaries containing corpora lutea. Examination of the uteri of these foxes showed that 2 were pregnant, 1 contained sperm but no visible signs of pregnancy, and 1 contained neither sperm nor fetuses. Since each egg ovulation is followed by the formation of a corpus luteum, the mean ovulation rate was 6.0 corpora lutea per female. None of the female reproductive tracts examined showed any signs of post-implantation mortality.

Ovulation rate based on the number of corpora lutea per vixen was calculated to be 5.9 for red foxes in New York (Layne and McKeon 1956). In Ohio, Gier (1947) reported 7.2 corpora lutea per female. The ovulation rate of 6.0 corpora lutea per female found in this study falls between the rates calculated for New York and Ohio, even though only four vixens we collected had ovaries containing corpora lutea.

Only one vixen which was captured on January 7, 1978 had sperm in the uterus. Two foxes were pregnant; one captured on January 27, 1978, the other on January 29, 1978. In both pregnant females the fetuses appeared to be about 7 to 10 days old, placing conception sometime between 17 and 22 January. In New York, Layne and McKeon (1956) found

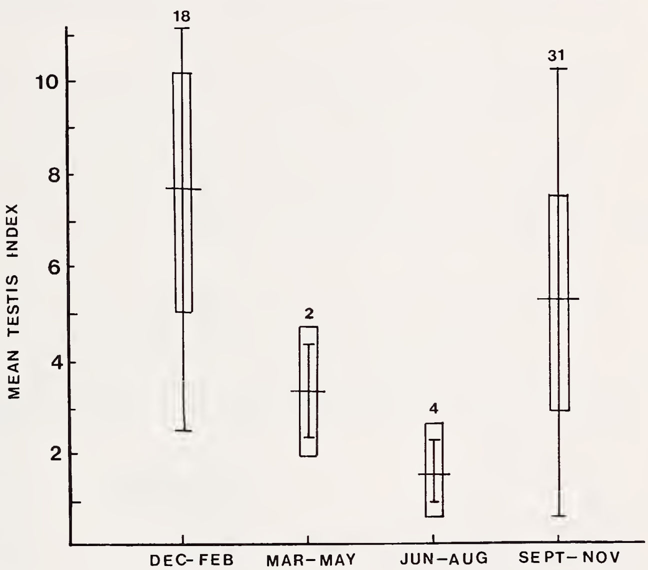

Fig. 2. Seasonal variations in mean testis indices for red foxes collected in Maryland (1976–1979). Vertical bars represent standard deviations, vertical lines are ranges, and numbers are sample sizes

8.3 % of the matings occurred the third week of January and 29.2 % occurred the fourth week of January. In Illinois and Iowa the peak of the breeding season was estimated to occur the third week of January (Storm et al. 1976). Generally, the peak of the breeding appears to be later in northern than in southern latitudes (Layne and McKeon 1956; Lloyd and Englund 1973).

Storm et al. (1976) found 4 % of the red foxes in Illinois conceived before mid-December, and three of 20 vixens bred between 13 and 29 December. Out of 52 vixens examined, Hoffman and Kirkpatrick (1954) reported 3 red foxes breeding in December. Although no fetuses were found, and no sperm was detected in the uterus, 1 fox caught on 15 December had 6 corpora lutea. It is possible that breeding may have occurred a few days prior to capture.

Sixty-seven percent of the adult males showed sperm production in October. Ninety percent of the adult males were producing sperm in November compared to 47 % in juveniles. By December, 60 % of the juveniles had testes containing sperm. The mean testis index increased from September to November and peaked from December to February (Fig. 2).

Testis weight and spermatogenesis are closely related in the red fox (Joffre 1977). From October through January, testes weight increases as the percent of red foxes with sperm in the testes increases (Lloyd and Englund 1973; Joffre 1976; Storm et al. 1976). In this study the occurrence of sperm in the testis increased from October through December in both juvenile and adult red foxes, except for a slight decrease for December adults. This decrease may be attributed to the small sample size of 6 adult males collected during this month.

The literature suggests that juveniles are capable of breeding their first year, but there is disagreement on the month that spermatogenesis begins. Storm et al. (1976) did not find sperm in juvenile testes until December in midwestern red foxes. In Ireland, Fairley (1970) found sperm in juvenile foxes in October. In this study 47 % of the juveniles had sperm in their testes in November. Whether spermatogenesis occurs in September and October in juveniles cannot be determined from this study since no juveniles were collected in September and only 1 was collected in October.

Mean litter size based on two pregnant females was 6.5, and for 41 females whose uteri contained placental scars it was 5.0. Analysis of variance of mean number of placental scars showed no significant difference between regions.

Litter size for red foxes has been determined using various techniques (Table 4). In this study the mean litter size was 6.5 based on 2 pregnant females. An estimate of 5.00 young per vixen (n = 41) was obtained from the number of placental scars per female. Both values are within the range of that reported in other studies (Table 4).

Females may breed during their first winter, but the proportion of vixens coming into heat their first year varies by different regions (Storm et al. 1976). Layne and McKeon (1956) reported as high as 16.6 % of the vixens were barren in northern New York

Table 4

Red fox mean litter size from different regions of the world

Reference	Location	Method	Mean Litter Size
Sheldon (1949)	New York	PS, E	5.4
Switzenberg (1950)	Upper Michigan	D	4.2
	Lower Michigan	D	5.4
Richards and Hine (1953)	Wisconsin	PS, D	5.1
Hoffman and Kirkpatrick (1954)	Indiana	PS, E	4.3–6.8
Layne and McKeon (1956)	New York	PS	5.4
		E	4.6
Schofield (1958)	Michigan	D	5.1
Stanley (1963)	Kansas	D	4.5
Fairley (1970)	Ireland	PS, E	4.5–5.4
Englund (1970)	Sweden	PS, E	3.1–6.8
Storm et al. (1976)	Illinois, Iowa	PS	7.1
		E	6.8
		D	4.2
Ryan (1976)	Australia	PS	3.7
		E	4.0
Insley (1977)	England	D	4.0
Pils and Martin (1978)	Wisconsin	PS, E, D	5.6
This Study (1982)	Maryland	PS	5.0

Abbrev. for methods of determination are: E = embryos or fetuses, D = number of young in den, and PS = placental scars compared to only 2.1 % in the southern part of the state. Five of the 6 barren vixens in this study were a year old and therefore had lived through only one breeding season.

The sex ratio of midwestern red foxes was found to significantly favor males (Storm et al. 1976). Fifty-four percent of the juveniles collected at dens were males and 56 % of the adults were males. In Wisconsin, 58 % of the red foxes collected were males (Pils and Martin 1978). However, the higher proportion of males collected suggests that males are more vulnerable to trapping, reflecting the tendency to travel more extensively than females, particularly during the fall (Sheldon 1949; Fairley 1970; Storm et al. 1976; Pils and Martin 1978). In this study there was no significant deviation from the 50 : 50 sex ratio.

Age distribution

Ossification of the proximal epiphysis of the humerus begins at nine months of age and has been reported to be a reliable technique for separating red foxes into juvenile, subadult, and adult age classes (Reilly and Curren 1961).

Table 5

Age distribution of red foxes collected in Maryland (1976–1979) using epiphyseal closure of the humerus

Epiphysis/Age	N	Relative Frequency (%)	Cumulative Frequency (%)
Open/Juvenile	47	22.4	22.4
Closing/Sub-adult	72	34.3	56.7
Closed/Adult	91	43.3	100.0
Total	210	100.0	100.0

Examination of the proximal epiphysis of the humerus of 210 red foxes revealed 22.4 % had no ossification, 34.3 % showed some ossification and 43.3 % were ossified completely (Table 5).

Eye lens weights were separated by age (Fig. 3). Although sample sizes were small, there was no overlap in ranges when compared to age classes determined by cementum annuli.

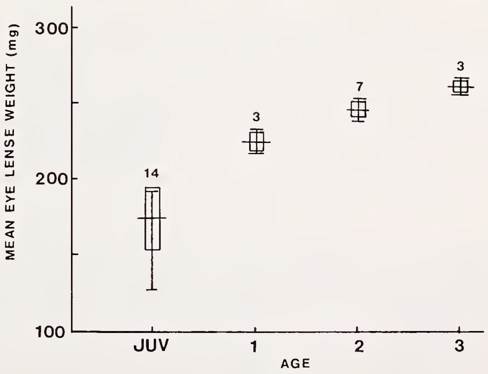

Fig. 3. Separation of mean eye lens weights by age for red foxes collected in Maryland (1976–1979). Vertical bars represent standard deviations, vertical lines are ranges, and numbers are sample sizes

Baculum weights showed a large overlap between age classes when compared to age classes determined by cementum annuli. Baculum weight was adjusted for body size by dividing it by total body length (× 10). Although overlap between age classes still occurred, significant differences existed between the means of juveniles and 1, 2, 3, and 5-year olds (Table 6).

Baculum weights from three juvenile red foxes collected on 10 July, 17 July, and 19 July were 28, 44, 89 milligrams, respectively. These three juveniles were the only animals collected before puberty began, and were estimated to be three to 3.5 months old if they were born the first or second week of April.

Table 6

Duncan's New Multiple Range Test for age variation in adjusted baculum weights for red foxes collected in Maryland (1976–1979)

Age Class (Years)	Difference in Means	Significance
Juvenile – 1	2.846 – 4.097 = –1.251	$p < 0.05$
1–2	4.097 – 4.184 = –0.087	$p < 0.05$
2–3	4.184 – 4.939 = –0.755	$p < 0.05$
3–4	4.939 – 3.508 = 1.431	$p < 0.05$
3–5	4.939 – 6.658 = –1.719	$p < 0.05$
Juvenile – 2	2.846 – 4.184 = –1.338	$p < 0.05$
Juvenile – 3	2.846 – 4.939 = –2.093	$p < 0.05$
Juvenile – 4	2.846 – 3.508 = –0.662	$p < 0.05$
Juvenile – 5	2.846 – 6.658 = –3.812	$p < 0.05$

Table 7

Age distribution of red foxes collected during two trapping seasons (October–January – 1977–78 and 1978–79) in Maryland

Age (Years)	1977–1978 Season Frequency	1977–1978 Season Relative Frequency	1978–1979 Season Frequency	1978–1979 Season Relative Frequency
Juvenile	53	55	45	52
1	16	17	17	20
2	15	16	13	15
3	8	8	6	7
4	2	2	3	4
5	1	1	2	2
6	1	1	0	0

Table 8

Analysis of variance of width of brain case by sex and by age class for red foxes collected in Maryland (1976–1979)

Group	N	Mean	S.D.	S.E.	Min.	Max.	95 % Confidence Interval For Mean	Significance
Males								
Juveniles	54	47.02	1.66	0.23	38.50	49.72	46.56 to 47.47	NS
Adults	39	46.92	1.10	0.18	45.11	49.05	46.56 to 47.27	
Total Males	93	46.98	1.44	0.15	38.50	49.72	46.68 to 47.27	$p < 0.01$
Females								
Juveniles	37	46.17	1.15	0.19	44.41	48.36	45.78 to 46.55	NS
Adults	38	46.11	1.23	0.20	43.29	48.32	45.71 to 46.51	
Total Females	75	46.14	1.18	0.14	43.29	48.36	45.86 to 46.41	$p < 0.01$

Table 9

Analysis of variance of zygomatic breadth by sex and by age class for red foxes collected in Maryland (1976–1979)

Group	N	Mean	S.D.	S.E.	Min.	Max.	95 % Confidence Interval For Mean	Significance
Male	97	74.32	3.11	0.32	61.70	82.76	73.69 to 74.95	$p < 0.01$
Female	78	70.38	2.69	0.30	63.44	75.81	69.77 to 70.99	
Juveniles	94	71.72	3.42	0.35	61.70	79.19	71.09 to 72.49	$p < 0.01$
Adults	81	73.46	3.44	0.38	66.64	82.76	72.70 to 74.22	
Males								
Juveniles	56	73.38	2.85	0.38	61.70	79.19	72.61 to 74.14	$p < 0.01$
Adults	41	75.61	3.02	0.47	67.27	82.76	64.65 to 76.56	
Females								
Juveniles	38	69.46	2.84	0.46	63.44	75.00	68.53 to 70.39	$p < 0.01$
Adults	40	712.6	2.25	0.36	66.64	75.81	70.54 to 71.98	

Aging red foxes by cementum annuli has been found to be a reliable aging technique in foxes (Grue and Jensen 1973; Monson et al. 1975; Geiger et al. 1977; Harris 1978). This technique agreed 100 % with the juvenile and adult age classes found using epiphyseal closure of the humerus. Sometimes several slices of the canine had to be made to clearly see the annular rings. The results of this technique were used to place eye lenses into age classes resulting in complete agreement between the 2 aging techniques (Table 7).

Of the cranial measurements taken, only width of brain case and zygomatic breadth showed significant differences between sexes and ages. These differences were sufficient to be used as an aging or sexing technique (Tables 8 and 9).

Population characteristics

The pattern of changing mortality rates with age is best expressed in the form of a life table (Caughley 1966). From the data in a life table, one may determine the population's rate of increase, mean life expectancy at birth, and percentage of the population that dies each year.

Survivorship ($x\chi$) is the probability at birth of an individual surviving to any age (χ). A clearer value is obtained by multiplying $1\,\chi$ by 1,000, which gives the number of animals surviving to age out of 1,000. Only 73 out of 1,000 red foxes reached 5-years of age (Table 9). The oldest female collected was 6-years old.

Mortality ($d\chi$) is the portion of the population that dies during the age interval χ, to $\chi + 1$. This value is usually expressed as 1,000 $d\chi$, the number of animals that die out of sample of 1,000 during the age interval χ, to $\chi + 1$.

Mortality rate ($q\chi$) is the number of animals that died during the interval χ, to $x + 1$, divided by the number of animals alive at age χ. The number of animals out of 1,000 alive at age χ which died before $x + 1$ is expressed as 1,000 $q\chi$. For Maryland red foxes the mortality rate was highest between birth and 1-year of age, and lowest between one year and two years of age (Table 10).

The age distribution remained relatively constant from the 1977–78 trapping season to the 1978–79 season (Table 7). Both years show that over 50 % of the population is comprised of juveniles and that after the age of 2 years the percent of individuals per year class drops.

When constructing a life table a possible source of bias is behavioral or range differences between males and females (Caughley 1966). If one sex is more vulnerable to the

Table 10

Life table for female red foxes collected during the trapping season (October–January) in Maryland

Age (Years)	1977–1978 Frequency	1977–1978 Adjusted Frequency	1978–1979 Frequency	1978–1979 Adjusted Frequency	No. Females Live Births Per Female at Age m_χ	d_χ	$1000\, l_\chi$	$1000\, q_\chi$
Juveniles	24	46.15	23	54.76	0.00	29.48	1000	558
1	9	17.31	7	16.67	2.66	3.02	442	129
2	8	15.38	6	14.29	3.34	8.24	385	405
3	5	9.62	3	7.14	3.13	4.86	229	402
4	3	5.77	2	4.76	3.05	3.39	140	468
5	2	3.85	1	2.38	3.01	3.85	73	1000
6	1	1.92	0	0.00	3.00	–	–	–

l_χ = fraction alive at start of age class; d_χ = number of dying during age class; q_χ = mortality rate per 1000 alive at start of age class.

collection method than the other, then the data will be biased. This bias was eliminated in this study by considering only females.

Not all age classes are equally vulnerable to the collection method, in this case trapping. If juveniles are more vulnerable to the trap, then distortions of each $x\chi$ and $d\chi$ value below the juvenile values in the series will result. However, the $q\chi$ values (mortality rates) are independent of the first age class (juveniles) since $q\chi$ is the ratio of the interval. The value of

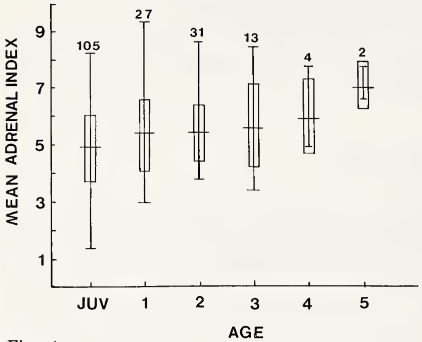

Fig. 4

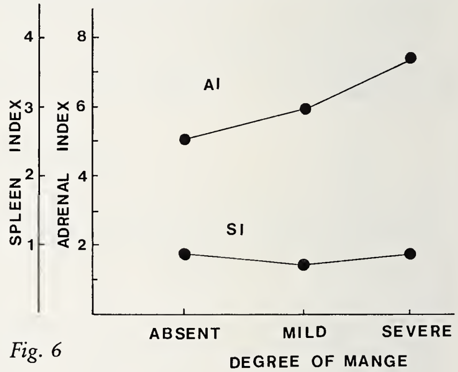

Fig. 6

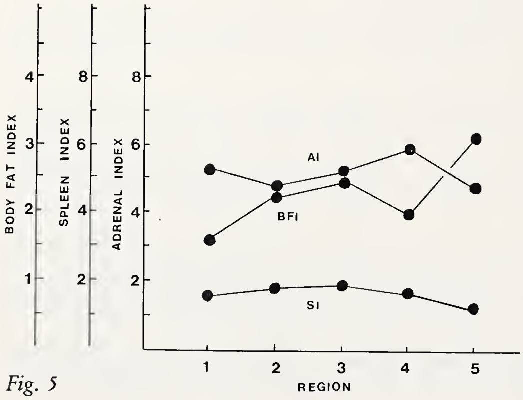

Fig. 5

Fig. 4. Age variation in mean adrenal indices for red foxes collected in Maryland (1976–1979). Vertical bars represent standard deviations, vertical lines are ranges, and numbers are sample sizes

Fig. 5. Comparison of adrenal indices, spleen indices and body fat indices for red foxes from 5-regions of Maryland (1976–1979)

Fig. 6. The effect of mange on adrenal and spleen indices of red foxes collected in Maryland (1976–1979)

$q\chi$ is not directly dependent on absolute values of 1χ, but on the differences between successive values (CAUGHLEY 1967). For Maryland red foxes the mortality rate ($q\chi$ value) was highest for juveniles (Table 9). If a red fox reaches one year of age it has a good chance of surviving to its second year (mortality rate = 129). At age 2 years mortality rates increase and remain high.

Physiological response

Spearman's Rank correlation coefficients were used to determine if there was any significant correlation between condition indices, month of capture, and weather parameters. Only month of capture showed a significant correlation with the adrenal index for both males and females. A significant correlation was shown between adrenal index and total precipitation, and spleen index and total precipitation for females but not males.

Age variations in mean adrenal indices showed juveniles to have the lowest AI value (Fig. 4). One, 2, and 3-year olds show a leveling off, of fairly constant adrenal indexes with a rise seen in 4 and 5-year olds. However, the difference in adrenal indices was significant only between juveniles and 5-year olds. Region 5, where the climate is the mildest, had the lowest adrenal index. Spleen indices were significantly different between juveniles, 3-year olds, and 5-year olds ($P < 0.05$).

A significant variation was found between the mean body fat index of summer and winter red foxes (males and females combined) ($P < 0.05$) and between fall and winter animals ($P < 0.05$). Significant regional variations in body fat indices were also observed ($P < 0.05$) (Fig. 5).

Ten red foxes were infected with mange and an attempt was made to assess the effect of mange on fox physiology (Fig. 6). Mild cases of mange were defined as having infected areas on the tail and sometimes the legs. Severe cases had mange covering most of the body, including the tail, legs, back, face, and ears. Adrenal indices were higher with increased severity of mange, whereas no trend was apparent for spleen indices. The variation between adrenal indices for absent and severe cases of mange was significant ($P < 0.05$).

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Zusammenfassung

Altersbestimmung und Populationsmerkmale beim Rotfuchs in Maryland

In den Jahren von 1976 bis 1979 wurden während der allgemeinen Fangzeit (Oktober bis Januar) im Staate Maryland, USA, insgesamt 210 Rotfüchse *(Vulpes vulpes)* gesammelt und ihr Alter bestimmt. Die Altersbestimmungen basierten auf Gewicht der Augenlinsen, Epiphysenschluß am Humerus, Baculumgewicht, Jahreszuwachs des Zahnzementes und Schädeldimensionen. Von den Füchsen waren 50 % juvenil, 20 % 1 Jahr alt, 16 % 2 Jahre alt, 8 % 3 Jahre alt und 4 % waren 4 Jahre oder älter. Aus der Anzahl der Corpora lutea pro Fähe konnte eine Ovulationsrate von 6,0 berechnet werden. Eine durchschnittliche Wurfgröße von 5,0 ergab sich aus der durchschnittlichen Anzahl von Plazentanarben pro Weibchen. Im Maximum findet die Fortpflanzung Mitte Januar statt. Im Oktober produzieren 67 % der adulten Rüden Spermien und im November 90 % der adulten und 47 % der juvenilen Männchen. Zur Bewertung der physischen Kondition wurden für jeden Fuchs Adrenalin-, Milz- und Körperfett-Indices ermittelt. Adrenalin- und Milz-Index zeigten an, daß 5jährige Tiere stärkerem Streß ausgesetzt sind als diejenigen jüngerer Altersklassen. Der Körperfett-Index ergab einen signifikanten Anstieg vom Herbst zum Winter und deutet auf beste körperliche Verfassung der

Tiere während der Fortpflanzungszeit hin. 10 Füchse waren von Räude infiziert. Signifikante Unterschiede im Adrenalin-Index ergaben sich zwischen gesunden und kranken Tieren.

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Home range and movement of sika deer *(Cervus nippon)* in Maryland

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Abstract

Studied the home ranges and movements of a radiocollared male and female sika deer. The home range area of the male was 182.5 ha; that of the female was 127.8 ha. The male also exhibited significantly greater mean movement throughout its home range than did the female.

Introduction

Sika deer (*Cervus nippon*, Temminck) are native to Japan, and eastern Asia from Manchuria south to Vietnam. Introduced populations currently exist in England, Ireland, several other European countries, Australia and New Zealand. In the United States, feral populations occur in Texas, Virginia, Wisconsin, Kansas, Oklahoma and Maryland (Feldhamer 1982). Sika deer are highly adaptable and thrive in many types of habitat. Despite the numerous introductions and wide distribution of the species, few studies on their home range or movement patterns have been conducted. Davidson (1979) investigated the linear distance from the point of tagging to kill site of 54 sika deer in New Zealand. Maruyama et. al. (1978) calculated the home range of two radiocollared sika deer in Japan.

The primary objective of this study was to determine the activity pattern and home range of sika deer relative to sex and season of the year. A secondary objective was to test the utility of the harmonic mean measure of home range calculation (Dixon and Chapman 1980) on a large mammal.

In Maryland, sika deer *(C. n. nippon)* occur throughout the southern portion of Dorchester County, where they are sympatric with native white-tailed deer (*Odocoileus virginianus*, Zimmermann) (Feldhamer et al. 1978). The study area was located south of Blackwater National Wildlife Refuge (Fig. 1). It consisted of a wooded tract dominated by loblolly pine (*Pinus taeda*, Linnaeus) and oak (*Quercus* sp., Linnaeus) with a dense understory of greenbrier (*Smilax* sp., Linnaeus), bayberry (*Myrica* sp., Linnaeus), American holly (*Ilex opaca*, Aiton) and poison ivy (*Rhus radicans*, Linnaeus). To the north and west of the wooded area was marshland, primarily three-square rush (*Scirpus olneyi*, Gray). The study area ranged in elevation from sea level to approximately 2–3 m. Following rain,

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