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Demographics And Condition Of Coyotes In Illinois

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DEMOGRAPHICS AND CONDITION
OF COYOTES IN ILLINOIS

LLOYD

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Demographics and condition of coyotes in Illinois

(TITLE)

BY

Daniel M. Lloyd ¹⁹⁷²⁻

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

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IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
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DEMOGRAPHICS AND CONDITION OF COYOTES IN ILLINOIS

Daniel M. Lloyd

Masters Thesis

Eastern Illinois University

Charleston, Illinois

ABSTRACT

This study examines the age structure, sex ratio, age-specific reproduction, and physical condition of coyote (*Canis latrans*) populations throughout the state. Since 1994, a total of 1,173 coyotes have been collected. Overall sex ratios did not differ from 1:1, however males comprised 54% of hunted coyotes. Age structure differed significantly among the 3 regions of Illinois. Juveniles made up 60% of the north and central regions, but only 45% of the southern region. The annual mortality rate estimated from the harvested sample ranged between 40-50% for ages 0.5 to 6.5 years old. The average number of placental scars per breeding female was 4.9, with 57% of the females breeding. Mean whole body weights differed between the sexes with males averaging 13.9 kg and females weighing 12.1 kg. Mean body length was found to be 121.9 cm for males and 117.3 cm for females. Kidney fat indexes were highest in juvenile and adult females (both 56%) and lowest in yearlings (41% for females and 40% for males). However, bone marrow lipids showed no significant differences between sex-age classes. Male % marrow lipids averaged 86.2% and females averaged 88.2%. Ovulating females had significantly higher skinned body weights than non-ovulating females among juveniles and yearlings. This study demonstrates that Illinois' coyotes are generally in good physical condition with high fat reserves and reproductive rates inspite of high population densities. However, reproductive rates (as indicated by placental scars) are lower than they were 20 years ago, when the population was rapidly expanding in Illinois.

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INTRODUCTION

Coyotes (*Canis latrans*) are both ecologically and economically important throughout their geographic range. Their ecological importance is due in part to the role they play as the dominant predator throughout much of the eastern United States, due to the loss of the gray wolf around 1900 (Parker 1995). They are economically important to the fur industry (Boggess 1982), and as a nuisance species when they depredate livestock (Andrews and Boggess 1978, Sterner and Shumake 1978, Hubert 1982). Consequently, coyotes have been of interest to researchers for decades and a large body of scientific research has accumulated on the species' ecology, behavior, and demographics (e.g. Gier 1968, Silver and Silver 1969, Knowlton 1972, Gipson et al. 1975, Andrews and Boggess 1978, Windberg et al. 1985, Andelt 1985).

Reported losses of sheep and other livestock to coyotes, particularly in western states, led to massive federal control efforts which included trapping, shooting and poisoning (Young and Jackson 1951, Sterner and Shumake 1978). However, reports on governmental predator control efforts in the late 60's and early 70's suggested that these efforts were not cost-effective. The Advisory Board on Wildlife Management recommended against the use of poisons for controlling coyote populations, and the United States government put an end to the use of toxicants for this purpose during the 1970's (Sterner and Shumake 1978). During this period it became clear that we needed a better understanding of the demographics, behavior, and life history of coyotes, if these populations were to be properly managed.

In Illinois, coyote densities were low through the 1960's. Hoffmeister (1989) stated that from 1950 to 1969 fewer than 10 coyotes were observed by researchers at the

Cooperative Wildlife Research Laboratory at Southern Illinois University. Until 1973, there was no state statute regarding the harvest of coyotes (Illinois Department of Natural Resources 1995, unpubl. report). However, beginning in the 1970's the population began to grow rapidly statewide. For a period of 19 years (1975-94) the estimated harvest of coyotes based on fur buyer reports ranged from 1,489 to 10,390 annually. These estimates provide only a crude index of population size, due to the fact that harvests are influenced by economics as well as population size. However, they suggest that the population has increased during the past 20 years. Recently (1991-94) the estimated annual harvest of coyotes has averaged 7,531 (IDNR 1995, unpubl. report).

The rapid growth in the coyote population prompted two studies in Illinois during the 1970's. Mahan and Gier (1977) examined age-structure and reproduction in coyotes primarily from southwestern Illinois. Hubert (1979) reported the results of surveys in which he assessed morphological characteristics and estimated sex ratios and reproductive rates statewide. However, prompted by the need for more current demographic data, and a recent initiative by the Illinois Department of Natural Resources (IDNR) to develop population models for managing Illinois' coyotes, my study was initiated to estimate the current demographics and physical condition of the coyote population statewide. The objectives for this research were to: (1) estimate age-structure and sex ratios of coyotes statewide, (2) estimate age-specific reproductive rates, and (3) evaluate the relationships among age, physical condition, and reproductive rates of female coyotes in Illinois.

METHODS

Coyotes were collected from December 1995 to February 1996 and from December 1996 to March 1997. Carcasses were collected from fur buyers, hunters, and trappers throughout Illinois. For each coyote, data was recorded on county harvested, sex, length (nose to end of tail) and skinned body weight. For purposes of comparison, the state of Illinois was divided into a northern, central, and southern section by grouping management regions developed from the natural divisions of the state (Fig. 1) (Schwegman 1973).

The method of harvest was determined by asking the hunter, trapper, or buyer and by examining wounds on the carcasses. Coyotes with prominent wounds to any area of the body other than the head were categorized as hunted animals. Individuals with wounds to the head determined to be more than necessary for dispatching the animal were also considered as hunted. Individuals with no apparent wounds at all or wounds only to the auditory canal were categorized as trapped animals.

To age individual coyotes the lower canine teeth were collected by removing the mandibles of coyotes and then soaking these in a water bath at 80° C for 3-4 days (Matson's Laboratory, unpubl. report 1996). The lower canines were extracted, cleaned and labeled with India ink. Teeth were taped to sheets of cardboard and radiographed using a Picker 3000 Radiograph. Juvenile canines were identified by the presence of a large pulp cavity (Kuehn and Berg 1981, Kuehn and Berg 1983, Jenks et al. 1984). Adult teeth were sent to Matson's Laboratory (Milltown, MT) where age was estimated by staining and counting cementum annuli (Linhart and Knowlton 1967). For this study,

juveniles were individuals approximately 0.5 years old, yearlings were 1.5 years old and adults were at least 2.5 years of age.

The physical condition of each coyote was estimated by measuring kidney (perirenal) fat and marrow fat in the femur. Kidney fat (often expressed as a kidney fat index, KFI; Riney 1955, Harder and Kirkpatrick 1994) is a fat reservoir that is particularly useful for this purpose. Stored lipids in the marrow of the femur are also used as an indicator of condition in mammals (Cheatum 1949a for white-tailed deer, Neiland 1970 for caribou, Hout et al. 1995 for coyotes). Hout et al. (1995) used several measurements to assess the physical condition of coyotes including ether-extracted lipid content of femur marrow, KFI, body weight and body length. Windberg et al. (1991) also examined body weight and body length, as well as intraperitoneal fat.

The kidney fat index was measured by weighing the fat surrounding both kidneys, dividing it by the weight of the kidneys, and multiplying by 100 (Riney 1955). The percentage of the femur marrow that was lipid was measured by dissecting marrow out of the middle 1/3 of the femur (Cheatum 1949a, Harder and Kirkpatrick 1994, Hout et al. 1995). Femur sections were frozen until the time of analysis, then each marrow sample was dried, weighed (nearest 0.001g), and the marrow extracted using petroleum ether. The ether extraction was carried out for 4 hours using a Soxhlet apparatus (Neiland 1970, Sawicka-Kapusta 1975, Dobush et al. 1985). Percent marrow fat was calculated by dividing the dry weight of marrow after ether extraction by the dry weight before extraction, and subtracting this ratio from 1 (Sawicka-Kapusta 1975).

In addition to these fat measurements, a visual estimate of the amount of fat lying along the back (approximately 30 cm proximal to the base of the tail along the vertebrae)

was recorded. Each coyote was then classified into 1 of 3 of the following categories: no fat, moderate fat, or a large amount of back fat.

Age-specific reproductive rates for Illinois' coyotes were estimated by collecting female reproductive tracts and counting placental scars and ovarian structures. Placental scar counts were used to estimate the litter sizes of female coyotes (Gier 1968), whereas the presence of corpora lutea in the ovaries indicated ovulations in the current year, and corpora albicantia were used to estimate ovulation rates in the previous year (Cheatum 1949b, Harder 1980). Reproductive tracts were frozen after collection and subsequently thawed and dissected for examination. The number of visible placental scars was recorded. All scars of the same color were considered to represent fetuses. Scars that were markedly lighter could represent fetuses of prior litters or reabsorbed fetuses (Gier 1968, Kennely 1978). The latter were noted but not used to estimate reproductive rates. Ovaries were collected and preserved in 10% formalin for sectioning (Hamlett 1938, Cheatum 1949b, Gipson et al. 1975). Each ovary was gross-sectioned to count corpora lutea and corpora albicantia.

Data analyses were carried out using the Statistical Analysis Systems program (SAS). P-values less than 0.05 were considered significant in these analyses. The chi-square contingency test was used to determine if sex ratios differed from a 1:1 ratio in each year, region, age class, and method of harvest. Also, this chi-square test was used to determine differences in age structures among regions, and in percentages of breeding females among age classes and regions. T-tests were used to examine differences in % marrow lipids between sexes, and differences in body weight and fat levels between breeding and non-breeding females. Pearson product-moment correlation coefficients

were used to identify correlations among all condition factors used in this study. The remainder of the analyses utilized multivariate ANOVA to test for significance among samples of unequal sizes.

RESULTS AND DISCUSSION

A total of 1,173 coyotes was collected and evaluated during this study. This total includes 81 coyotes collected in 1994-95, 458 coyotes collected in 1995-96, and 634 in 1996-97 (Table 1). The sample was fairly evenly distributed among the 3 regions of the state (Fig. 1); 32% (N=378) were harvested in northern Illinois, 26% (N=300) in central Illinois, and 42% (N=495) in southern Illinois. Hunters harvested 69% of these coyotes, whereas trappers harvested the remaining 31% (Table 1). Hunted coyotes were most prevalent in southern and northern regions, where they accounted for 87.5% and 66.7% of the sample, respectively (Table 1). In contrast, trappers took the majority (57.7%) of coyotes in central Illinois. Sixty-three percent of juvenile coyotes were obtained through hunting and 36% were trapped.

Sex Ratio

Females comprised 45%, 49%, and 44% of the sample in 1994, 1995, and 1996, respectively (Table 2). Sex ratios did not differ significantly from 1:1 in any year ($P = 0.06-0.82$) or region ($P = 0.10-0.54$). The sex ratio of the trapped sample did not differ from 1:1 ($X^2 = 0.41$; 1 df; $P = 0.52$); however, males predominated in the hunted sample, where they comprised 54% ($X^2 = 5.77$; 1 df; $P = 0.02$). Further, sex ratios differed among age-classes ($X^2 = 9.52$; 3 df; $P = 0.02$). Females comprised 49% of the juvenile age-class, 51% of yearlings, but only 39% of adults (Table 2). Thus it appears that either female coyotes experience higher mortality rates than males after their second year, or these females are less vulnerable to harvest than males, and are under-represented in the sample. There is no obvious reason why natural mortality rates for adult females should exceed those of adult males, so I conclude that the higher proportion of males in the older age

classes reflects the greater vulnerability of males to hunting. This vulnerability to hunting may be due to greater movements of males. Pyrah (1984) found that of "nomad" coyotes (those not in social groups), males had traveled over larger areas ($\bar{x} = 146 \text{ km}^2$) than females ($\bar{x} = 76 \text{ km}^2$). Berg and Chesness (1978) reported that males had larger home ranges than females in northern Minnesota, where males averaged 68 km^2 and females averaged 16 km^2 . Juvenile males also dispersed greater distances than juvenile females. Windberg et al. (1985) also found that movement distances between capture and death averaged 6.4 km for adult males and 3.4 km for adult females. However, juvenile females moved the greatest distances in that study, and the authors believed this to be emigration from the population.

There appears to be no consensus among researchers on what sex ratios indicate about the dynamics of coyote populations, or the relative vulnerability of either sex to harvest. Knowlton (1972) found equal sex ratios in lightly-harvested coyote populations in Texas, but ratios were skewed towards females in more heavily harvested populations. He believed that females were more vulnerable to harvest during winter months, as they were the primary dispersers in the population. Hubert (1978) reported that females comprised 46% of 203 harvested coyotes that he inspected in Illinois in 1977-78, and 43% of 214 in 1978-79 (Hubert 1979). This was at a time when the population was rapidly growing throughout the state. Gese et al. (1989) found a 1:1 sex ratio in a "lightly exploited" coyote population in Colorado, as did Todd et al. (1981) in Alberta. However, Moore and Millar (1984) found males predominated over females (72:39) in colonizing populations in New Brunswick and Nova Scotia. Andrews and Boggess (1978) also

found a significant preponderance of males (53.2%) among harvested coyotes in Iowa and hypothesized that females were less vulnerable to harvest. My data suggest that sex ratios are balanced throughout Illinois. However, males may be more vulnerable to harvest by hunters, and may be over-represented in hunted samples.

Age-structure

The age-structure of the sample of coyotes examined during this study was 56% juveniles, 20% yearlings, 24% adults (Table 2). Adult males made up 15%, and adult females 9% of the population (Table 2). However, age-structure differed significantly between regions of the state ($X^2 = 22.1$; 8 df; $P = 0.001$); northern and central Illinois samples had proportionately more juveniles. Specifically, juveniles comprised approximately 60% of the sample in northern and central regions, but only 45% in the south. Adults comprised a smaller proportion of the population in the northern and central regions (8-9%) than in southern Illinois (14%).

The age-structure of a sample of 36 harvested coyotes collected during 1977 in southern Illinois was 55% adults and only 17% juveniles (Mahan and Gier 1977). Due to the high percentage of adults in this sample, the authors concluded that Illinois coyote populations might be in decline, at least in southern Illinois. However, low proportions of juveniles can result from either low recruitment, high adult survival, or both. My results suggest that the percentage of adults is higher in southern Illinois compared to other portions of the state, but considerably lower than reported in this earlier study.

Reported age-structures for coyote populations throughout North America have varied considerably. In one of the larger studies, Knowlton (1972) reported that 49.5% of coyotes in Texas were juveniles and 50.4% were yearlings and adults. In Alberta, Todd et

al. (1981) found that 55% of harvested coyotes were juveniles, 28% yearlings, and 17% adults. Windberg (1995), in a recent Texas study, reported 34% juveniles, 19% yearlings, and 47% adults. In contrast, the percentage of juveniles has been found to be much lower (23%) in a Colorado study where 18% of the sample was yearlings, and 59% adults (Gese et al. 1989). Both of the latter studies were conducted on populations described as "lightly exploited". High percentages of adults in these populations may have been due to low adult mortality, high population densities, and low recruitment.

Age-structures differed between hunted and trapped samples ($X^2 = 6.82$; 2 df, $P = 0.03$, Fig. 2). Adults comprised 28% of the hunted sample, but only 20% of the trapped sample. Yearlings represented 20-22% of the hunted and trapped samples, respectively, while juveniles made up 52% of the hunted sample and 58% of the trapped sample. Adults were under-represented in the trapped sample, and juveniles were over-represented in this sample compared to the hunted sample. These data suggest that juveniles are more vulnerable to trapping than to adults.

Wetmore et al. (1970) found that juveniles comprised 81% of hunter-harvested coyotes in Alberta, and attributed this to their observation that young animals were less wary of hunters and snowmobiles. They also showed that juveniles were less wary and more vulnerable to traps, poisoning, and other human-caused mortality. However, Windberg et al. (1985) reported that in a marked sample of 35 coyotes, adults and juveniles appeared to be equally vulnerable to trapping and hunting.

Life Table for Illinois coyotes

It is possible to generate a life table for Illinois' coyotes based on the ages at death of individuals in my sample, if 3 assumptions are met: (1) the sample is an unbiased

representation of the true frequency of ages at death, (2) age-specific fecundity and mortality have remained essentially unchanged for several generations, and (3) the population has a rate of increase close to 0 (Caughley and Sinclair 1994). While trapping appears to be biased towards juveniles, the hunted sample appears to be less biased based on mortality rates for the first four years of life. No continuous data are available on fecundity or mortality rates for Illinois coyotes, or rates of population increase. However, a population index based on surveys of deer hunters for 1991-96 suggests that the Illinois coyote population has been stable (Ver Steeg and Warner 1997).

If these assumptions hold, then several patterns are apparent in the life table generated from the sample of harvested coyotes (Table 3). Age-specific mortality (q_x) appears to be highest among coyotes in the first and third year of life, suggesting that survival is lowest during the juvenile period, and again when young adults are establishing territories. Gese et al. (1989) noted that fall and winter dispersers were usually juveniles and that coyote survival was lowest at that time of the year. Andelt (1985) also showed that transients, those searching for territories, had higher rates of mortality in Texas. Through the first 6 years of life, Illinois' coyotes experience annual mortality rates that are relatively constant, ranging from approximately 40-50% each year. Life expectancy for those juveniles surviving to their first winter is 1.3 years, but expectancy remains relatively constant through the first 8 years of life (Table 3).

Age-specific Reproduction

The percentage of females that bred differed significantly among age-classes ($X^2 = 219.16$; 2 df; $P = 0.001$). Statewide, 88% of all adult females had bred, as had 57% of yearlings and 44% of juveniles (Table 4). The percentage of juveniles breeding did not

differ among regions ($X^2 = 4.17$; 2 df; $P = 0.12$), however, juveniles from northern and southern Illinois were more likely to breed than their counterparts in central Illinois (Table 4).

Among breeding females, fetal rates (as indicated by placental scars) differed among age-classes ($F = 8.34$; 2 df; $P = 0.0004$). Adult females averaged 5.9 fetuses, whereas yearlings and juveniles averaged 5.1 and 4.0 fetuses, respectively (Table 4). The mean number of fetuses produced by adult coyotes did not differ significantly among regions ($F = 0.74$; 2 df; $P = 0.48$); however adults in the northern and central regions averaged 6.5 and 5.9 fetuses, respectively, while southern females averaged 5.3 fetuses, suggesting a positive latitudinal trend. Fetal rates of yearlings did not differ among regions ($F = 0.70$; 2 df; $P = 0.50$). Juveniles from northern Illinois averaged 4.4 fetuses, while those from central and southern Illinois averaged 3.5 and 3.9 fetuses, respectively (Table 4).

Hubert (1978) reported a mean of 6.8 placental scars/breeding female among 70 females in a previous study conducted in Illinois. However, 90% of the females in this sample had not bred (Table 5). Also, in 1979, Hubert found a mean of 6.9 placental scars/breeding female from a sample of 62 females in which 69% had not bred. Moore and Millar (1984) found 5.9 placental scars/breeding female in coyotes from eastern North America. Gese et al. (1989) found that adults in Colorado averaged 3.4 placental scars/breeding female ($n=10$), but reported finding no placental scars in the uteri of 11 yearlings (Table 5).

Several authors have compared the number of placental scars with litter size at birth, and found the numbers to be similar (Gier 1968, Nellis and Keith 1976, Gese et al.

1989). Uterine swellings tend to over-estimate litter size by 10-15% (Todd and Keith 1983), suggesting some additional losses occur in late gestation due to resorption. However, no significant difference was found between litter size and placental scar counts when only full-term placental scars are counted, as in my study.

Ovarian Structures

Ovaries of females in each age-class were examined for luteal structures (corpora lutea and corpora albicantia). The corpus luteum (CL) is a visible endocrine structure formed immediately after ovulation, while the corpora albicantia (CA) are visible scars formed by CL from the previous year (Harder 1980). These can be used to estimate the number of ova shed annually by a female, and compared to the number of placental scars to estimate the percentage of ova and/or embryos lost after ovulation (Harder and Kirkpatrick 1994). Most of the females in my sample were harvested between December and January, prior to the onset of estrus. Consequently, few females in any age-class had ovulated yet and produced CL. However, CA were apparent in many ovaries. Among adult females, CA were found in 85% of the ovaries examined (indicating ovulation during the previous year), but 88% had placental scars indicating that they had carried fetuses. The discrepancy between these two figures probably occurred because CA were overlooked during gross inspection of ovaries. Similarly, only 51% of 2-year olds and 28% of yearlings had CA, but 57% of 2-year olds and 44% of yearlings had placental scars (Table 6).

Knowlton (1972) found the mean ovulation rate to be 62% across all age-classes in Texas. Todd et al. (1981) found 97-100% of adult females in Alberta had ovulated. Windberg (1995) reported that 93% of adults and 67% of yearlings had ovulated in his

sample of coyotes in Texas. Therefore, it appears that the percentage of female coyotes ovulating and reproducing in Illinois is comparable to that reported from other parts of the species' range.

Based on the proportion of females in each age-class, the proportion of these females that breed, and their estimated fetal rates, the potential natality of each age-class can be estimated for a sample population of 1,000 female coyotes (Table 7). Overall, the Illinois coyote population produces approximately 3 fetuses/female. Adult females produce 46% of all offspring, while juveniles produce 33%, and yearlings 21%. Although adult breeders are clearly the most important age-class influencing the growth of the population, juveniles contribute substantially to potential natality because they are the largest age-class. Windberg (1995) reported that the potential natality of coyotes was positively correlated to prey availability, and negatively correlated to the number of coyotes within the population.

Assessment of Physical Condition

Yearling males had a mean skinned body weight of 12.0 kg which was not significantly heavier than the skinned body weight for adult males of 11.9 kg (Table 8). Yearling males were significantly heavier than juvenile males which had a mean skinned body weight of 11.3 kg. Females weighed less than the males of comparable age, but I found no difference in body weight among females of different age. Yearling females were found to have a mean skinned body weight of 10.0 kg, adult females weighed 9.8 kg, and juvenile females averaged 9.4 kg.

The skinned weights of most sex-age classes did not differ among the three regions of the state ($F = 0.09-2.6$; $P = 0.08-0.91$); however, adult females were heavier in

central Illinois ($F = 4.17$; 2 df, $P = 0.02$), as were yearling males ($F = 4.84$; 2 df, $P = 0.01$).

Body weights of the sex-age classes did not differ among the three years of the study ($F = 0.54$; 10 df, $P = 0.86$).

The simple linear regression between skinned weight and whole weight was calculated for a sample of 15 adult males and 20 females from central Illinois which had been weighed, skinned and re-weighed. These relationships can be useful to biologists when they want to calculate whole body weight from skinned weight or vice versa:

$$\text{Males: whole weight in kg} = 1.18 (\text{skinned weight in kg}) + 0.33$$

$$\text{Females: whole weight in kg} = 1.20 (\text{skinned weight in kg}) + 0.38$$

Hubert (1978) calculated the linear regression between whole and skinned weights for 28 male and 31 female coyotes in Illinois. He reported:

$$\text{Males: whole weight} = 1.19 (\text{skinned weight in kg}) - 0.32$$

$$\text{Females: whole weight} = 1.13 (\text{skinned weight in kg}) + 0.23$$

Body weights of coyotes from several states and provinces have been reported previously, and an increase in weight from the southwest U.S. to the northeast U.S. is evident (Table 9). Coyotes in Illinois are quite large, corresponding most closely in weight with those from the northern Midwest and Canada.

The mean body length of males was 121.9 cm and 117.3 cm for females ($F = 81.20$; 1 df, $P = 0.0001$; Table 10). As with weights, the body length of coyotes shows a positive latitudinal gradient. For example, males in the Yukon Territory averaged 126.5 cm in length and females 119.9 cm (Young and Jackson 1951). Richens and Hugie (1974) reported that male and female coyotes in Maine averaged 125.1 cm and 117.9 cm, respectively. In contrast, the mean length of males in Texas was 86.4 cm, and females averaged 82.1 cm (Windberg et al. 1991). My measurements suggest that coyotes in

Illinois are comparable in length to coyotes in the northern U.S. and Canada, and larger than those in the Southwest.

To better assess the relevance of body weight as an indicator of physical condition, the skinned weight (kg) of each coyote was divided by body length (cm) to compensate for the skeletal size of each individual. Weight/length ratios for the classes ranged from 0.075 for juvenile females to 0.085 for adult females, and from 0.089 for juvenile males to 0.096 for adult males (Table 11). No interaction between sex-age class and region were observed ($F = 0.44$; 8 df, $P=0.90$).

Mammals typically store lipids in specific locations throughout the body. These include: bone marrow fat, kidney (perirenal) fat, subcutaneous fat, cardiac fat, and intraperitoneal fat (Bear 1971, Kistner et al. 1980, Mech and Delgiudice 1985). Biologists have used fat measurements to assess the physical condition of individuals, and to compare the relative nutritional status of populations and sex-age classes. Because the coyote carcasses that I collected from Illinois' fur buyers were usually skinned and frozen, it was difficult to assess intraperitoneal and subcutaneous fat. However, kidney fat deposits and marrow fat (from femurs) were collected and measured.

Kidney fat indexes (KFI) were significantly lower in yearling males and yearling females than in all other classes except adult males (Table 12). KFI's of adult females, juvenile females, and juvenile males were highest, averaging 55-56%. Adult males had a mean KFI of 46%, whereas yearlings averaged only 40-41%. No interaction between class and region of the state were noted ($F = 1.04$; 10 df, $P = 0.41$).

Todd and Keith (1983) visually estimated the perirenal fat of coyotes from Alberta and found that adults had more fat than juveniles. Intraperitoneal fat did not differ among

sex-age classes of coyotes in Texas (Windberg et al. 1991). However, these authors reported that yearlings only showed decreases in fat (but not body weight) from fall to spring, whereas adults showed decreases in fat and body weight for the same period. They concluded that fat indices may be better indicators of condition than body weight alone. They also noted that few juveniles in this high density population reproduced, and the decline in body weight observed in adults may have been due to the higher energy demands on reproducing adults and lowered food intake by adult females during the perinatal period.

Because a very large percentage of the females in my sample were collected from December through February, prior to the beginning of gestation for Illinois coyotes (Hubert 1979), the high energy demands of pregnancy would not have affected the stored energy reserves of these individuals. Consequently, I speculate that adult females in Illinois may have high stored fat reserves during this period in preparation for the demands of pregnancy and lactation. In contrast, yearlings may have less fat due to their low social status (Windberg 1995) which may affect the quality of foraging habitat available to them.

I evaluated the % lipid composition of bone marrow to determine whether this varied among classes or among regions of the state. Little research has been done on marrow lipids in canids; most of this work has been conducted on ungulates and only lately on carnivores (Hout et al. 1995). However, in their examination of coyotes these authors reported that % marrow lipids, used in conjunction with KFI, were the best indicators of the condition, and that these indices were highly correlated with total body fat. Ransom (1965) assessed lipid reserves in white-tailed deer (*Odocoileus virginianus*), and found that marrow lipids reflected declining physical condition only after the KFI

reached a low level ($< 30\%$). He suggested that bone marrow is the last reservoir for fat to be utilized when an animal starves. As such, % lipid composition tends to be low only in those individuals in very poor condition, and both KFI and marrow lipids are needed to quantify the range of physical condition from very poor to excellent.

Marrow lipid levels were high in both sexes of coyotes in my sample, and did not differ between males and females, averaging 86.2% and 88.2% respectively ($t = 1.14$; 119 df; $P = 0.26$). Adult males had the lowest % marrow lipids with 71.1% (Table 13). No significant difference was found in marrow fat levels among coyotes in the 3 regions of the state. Coyotes in southern Illinois averaged 85.6% ($n=30$), those in central Illinois averaged 88.1% ($n=35$), and those in northern Illinois averaged 87.4% ($n=56$). This was expected because most coyotes had high kidney fat reserves, thus the marrow lipids were not utilized. No individual measured had less than 16.7% bone marrow lipids. The combination of high KFI's and high marrow fat suggest that the coyotes I examined had relatively high energy reserves through late-fall and early-winter and were overall in very good condition.

I found no significant correlations between KFI and skinned body weight ($r = 0.08$; $P = 0.08$) or between KFI and % marrow lipids ($r = 0.11$; $P = 0.27$). However, % marrow lipids and skinned body weight were weakly and negatively correlated ($r = -0.21$; $P = 0.035$). Few individuals in my sample had KFI's less than 30%. A previous study reported that marrow lipids and kidney fat were correlated ($r^2 = 0.44$) in gray wolves, but marrow lipid concentrations decreased only after kidney fat levels were $< 20\%$ (LaJeunesse and Peterson 1993). These authors stated that kidney fat, subcutaneous fat, and visceral fat were utilized first, and marrow fat was used "only after exhaustion of all

other fat reserves". They found positive correlations between various fat reserves (e.g. KFI and visceral fat, $r^2 = 0.45$; visceral fat and subcutaneous fat, $r^2 = 0.43$), and suggested that these other reserves were used simultaneously. Although they did note that kidney fat reserves were the last to be used before bone marrow fat was utilized. However, Harris (1945) and Mech and Delgiudice (1985) reported that mammals use these lipid reservoirs in succession.

Physical Condition and Breeding in Female Coyotes

I evaluated the relationship between the physical condition of females and reproduction by comparing body weights, weight/length ratios, KFI's, and % marrow fat between females that had ovulated versus those that had not ovulated, and between those that had placental scars and those that lacked placental scars. Few studies have attempted to relate female reproduction and body condition for coyotes. The influence of age and food abundance on pregnancy rates have been studied in coyote populations (Gier 1968, Nellis and Keith 1976, Todd et al. 1981, Todd and Keith 1983), but few researchers have assessed the relationship between physical condition and reproduction in individual coyotes. Windberg (1995) examined body weights of yearlings that ovulated versus those that did not and found yearlings that did not ovulate weighed less (8.1 kg) than those that had ovulated (8.7-9.0 kg., $P < 0.04$). I was particularly interested in whether yearlings that had bred as juveniles were larger than those that did not breed, and whether females that had bred the previous year would have lower weights or less fat (due to the energetic costs of reproduction) versus females that had not bred.

Yearling breeders (as indicated by the presence of placental scars) were not significantly heavier than non-breeders ($t = 0.36$; $P = 0.72$), and KFI's did not differ

between these 2 groups ($t = 0.59$; $P = 0.56$). Adult females that had bred did not differ in either weight ($t = 1.03$; $P = 0.31$) or KFI ($t = 0.59$; $P = 0.56$) from non-breeders.

Apparently the quality of Illinois habitat is sufficient for breeding female coyotes to regain fat reserves by early winter. Also, the visual estimates of fat could not be used predict whether a female would have placental scars or not; breeders and non-breeders did not differ in any of the visual indices ($P = 0.10-0.78$).

However, juvenile and yearling females may have to reach a critical weight (or fat level) to ovulate. Juvenile coyotes that ovulated weighed more (11.1 kg skinned body weight) than those that did not (9.2 kg) ($t = 4.57$; $P = 0.0006$). In addition, yearlings that ovulated weighed more than non-ovulating yearlings, 10.7 kg and 9.5 kg skinned body weights respectively ($t = 2.40$; $P = 0.021$).

MANAGEMENT IMPLICATIONS

The overall sex ratio in my sample was not significantly different than 1:1, however males predominated in the adult age-class. I believe that the low percentage of adult females in my sample is because females are less vulnerable to harvest in Illinois, and not because they are a smaller proportion of the population. Balanced sex ratios appear to be typical in lightly-harvested coyote populations (Knowlton 1972, Todd et al. 1981, Gese et al. 1989), and other researchers have reported that adult males may be more vulnerable because they are more active (Andrews and Boggess 1978, Moore and Millar 1984) and have larger home ranges (Berg and Chesness 1978, Pyrah 1984, Windberg et al. 1985). This suggests that Illinois coyotes cannot be considered heavily exploited. This bias should be recognized when modeling coyote populations for management.

A large proportion of my sample was juveniles. In conjunction with high reproductive rates, this suggests that recruitment rates are relatively high. Several researchers have suggested that coyote populations near carrying capacity exhibit low reproductive rates, and have high proportions of adults in the population (Gese et al. 1989, Windberg 1995). My results suggest that coyotes in Illinois have not reached threshold densities that trigger significant reductions in reproduction or recruitment. However, current reproductive rates appear to be somewhat lower than those reported by Hubert (1978, 1979) 20 years ago, suggesting that some density-dependent regulation of reproduction may be occurring.

Mortality was found to be highest among juveniles and 2-year olds. High juvenile mortality is usually attributed to high vulnerability to predation and starvation due to inexperience and/or low social status (Gese et al. 1989). Two-year olds may be more

vulnerable to hunters, trappers, and predators as they emigrate from their natal areas to establish their own territories (Andelt 1985). However, the apparent vulnerability of 2-year olds may be a sampling artifact. Males were generally more vulnerable to harvest, and 64% of the 2-year olds in my sample were male. Survivorship is relatively high and consistent among other age-classes.

Coyotes in Illinois appear to be in excellent physical condition. Body weights are comparable to other populations in the Midwest, and differ little among the 3 regions of the state. Juveniles are relatively large at 6-months, and individuals are full-grown by the time they reach 1.5 years of age. Body fat levels in winter are high. KFI's were generally above 40, and % marrow fat for most individuals was over 80%. Very few individuals were in such poor condition that marrow fat concentrations were utilized. Therefore, this index of condition is not useful for monitoring condition over the high range of condition exhibited by most coyotes in Illinois. KFI was more variable, and although it did not correlate with body weight or weight/length ratio, females with higher KFI were more likely to ovulate early, suggesting that this index may be an important indicator of physical condition.

In summary, my data suggest that Illinois coyote populations have not reached densities sufficient to result in severe reduction of reproduction or recruitment, but there is some evidence reproduction is not as high as it was in the 1970's, and this may be due to density-dependent mechanisms. Reproduction and recruitment is high in all 3 regions of the state. Individuals are, on average, in good condition with high body weights and fat levels. The data collected in this study provides basic demographic information needed to

manage coyotes statewide, and sets the stage for the development of population models which may give even better insight into coyotes in Illinois.

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Table 1. Number of coyotes harvested by hunters and trappers in northern, central and southern Illinois that were examined during this study, 1994-97.

	1994-95		1995-96		1996-97		
<u>Region</u>	<u>Hunted</u>	<u>Trapped</u>	<u>Hunted</u>	<u>Trapped</u>	<u>Hunted</u>	<u>Trapped</u>	<u>Total</u>
North	0	0	67	53	185	73	378
Central	0	0	82	118	45	55	300
South	73	8	124	14	236	40	495
TOTAL	73	8	273	185	466	168	1,173

Table 2. Number and percentage of coyotes that were aged in each sex-age class annually throughout Illinois.

Sex-age class	1994-95	1995-96	1996-97	Total
Juvenile female	21 (27%)	131 (29%)	109 (24%)	261 (27%)
Yearling female	7 (9%)	48 (11%)	47 (10%)	102 (10%)
Adult female	7 (9%)	39 (9%)	48 (10%)	94 (9%)
Juvenile male	15 (19%)	123 (28%)	135 (30%)	273 (28%)
Yearling male	14 (18%)	40 (9%)	45 (10%)	99 (10%)
Adult male	13 (17%)	62 (14%)	73 (16%)	148 (15%)
TOTAL	77	443	457	977 (100%)

Table 3. Life table of Illinois' coyotes estimated indirectly from the age-at-death of harvested individuals, 1994-97.

Age (x)	Frequency $f_{(x)}$	Mortality $d_{(x)}$	Survivorship $l_{(x)}$	Age-specific mortality $q_{(x)}$	Life expectancy $e_{(x)}$
0.5	542	0.544	1.000	0.544	1.3
1.5	205	0.206	0.456	0.452	1.7
2.5	144	0.145	0.250	0.580	1.2
3.5	41	0.041	0.105	0.390	2.0
4.5	21	0.021	0.064	0.328	2.5
5.5	18	0.018	0.043	0.419	1.8
6.5	8	0.008	0.025	0.320	2.6
7.5	6	0.006	0.017	0.352	2.3
8.5	7	0.007	0.011	0.778	1.1
9.5	1	0.001	0.004	0.500	3.5
10.5	1	0.001	0.003	0.333	2.5
11.5	2	0.002	0.002	1.000	0.5

Table 4. Age-specific reproductive rates of female coyotes in northern, central, and southern Illinois based on placental scars in harvested coyotes, 1994-97.

<u>Age-class</u>	<u>Region</u>	<u>N</u>	<u>Prop. breeding</u>	<u>Placental scars/ breeding female</u>
Juveniles	North	32	0.50	4.4
	Central	36	0.31	3.5
	South	30	0.53	3.9
	Statewide	98	0.44	4.0
Yearlings	North	17	0.59	4.5
	Central	11	0.91	5.9
	South	21	0.38	5.0
	Statewide	49	0.57	5.1
Adults	North	13	0.92	6.5
	Central	14	0.93	5.9
	South	14	0.79	5.3
	Statewide	41	0.88	5.9

Table 5. Comparison of placental scar data reported from the United States and Canada.

<u>State/Province</u>	<u>Author(s)</u>	<u>N*</u>	<u>% breeding*</u>	<u>Mean placental scar/breeding female</u>
Quebec	Jean and Bergeron, 1984	116	0.46	7.1
Illinois	Hubert, 1979	62	0.31	6.9
Illinois	Hubert, 1978	70	0.10	6.8
New Brunswick, Nova Scotia, and New Hampshire	Moore and Millar, 1984	26	-	5.9
Kansas	Gier, 1968	-	0.48-0.50	5.6
Texas	Knowlton, 1972	123	0.54	5.6
Texas	Windberg, 1995	119	-	5.3
Illinois	Lloyd, 1998	188	0.57	4.9
Arkansas	Gipson et al., 1975	70	0.74	4.5
Illinois	Mahan and Gier, 1977	15	0.20	4.3
Colorado	Gese et al., 1989	21	0.48	3.4

* Some authors did not report age-specific reproduction.

Table 6. Proportion of female coyotes ovulating in each age-class and proportion with fetuses based on presence of corpora albicantia and placental scars, respectively, among harvested coyotes from Illinois, 1994-97.

<u>Age-class</u>	<u>N</u>	<u>Proportion ovulating</u>	<u>Proportion with fetuses</u>
Juveniles	98	0.28	0.44
Yearlings	49	0.51	0.57
Adults	41	0.85	0.88

Table 7. Estimated number of fetuses produced by female coyotes in each age-class in a representative sample of 1,000 females.

<u>Age-class</u>	<u>N</u>	<u>Proportion breeding</u>	<u>Mean no. fetuses/ breeding female</u>	<u>Total fetuses</u>
Juveniles	544	0.44	4.0	957 (33%)
Yearlings	204	0.57	5.1	593 (21%)
Adults	<u>252</u>	0.88	5.9	<u>1308</u> (46%)
Total	1000			2858

Table 8. Sample size, mean, standard error, and range of skinned body weights (kg) for six sex-age classes of coyotes in Illinois, 1994-1997.

<u>Sex - Age Class</u>	<u>N</u>	<u>Mean</u> ¹	<u>SE</u>	<u>Range</u>
Yearling Male	78	12.0 ^a	0.2	6.8 - 16.8
Adult Male	102	11.9 ^{a,b}	0.2	6.8 - 17.7
Juvenile Male	190	11.3 ^b	0.1	5.4 - 17.2
Yearling Female	70	10.0 ^c	0.2	5.4 - 14.5
Adult Female	65	9.8 ^c	0.2	5.4 - 19.5
Juvenile Female	156	9.4 ^c	0.1	4.1 - 14.1

¹Means with different superscripts are significantly different at $\alpha = 0.05$.

Table 9. Mean whole body weights of male and female coyotes reported from the United States and Canada.

<u>State</u>	<u>Author(s)</u>	<u>$\bar{x}$ Whole Body Weight (kg)</u>	
		<u>Male</u>	<u>Female</u>
Maine	Richens and Hugie, 1974	15.8	13.7
SE Quebec	Hout et al., 1995	13.9	12.0
Illinois	Lloyd, 1998	14.0	12.0
Minnesota	Chesness, 1973*	13.6	11.3
Iowa	Boggess, 1975*	13.4	11.4
Texas	Young and Jackson, 1951	12.6	10.5
New Mexico	Young and Jackson, 1951	11.1	10.1
Texas	Windberg, 1991	11.0	9.4
California	Hawthorne, 1971*	10.9	9.5

* Studies cited in Andrews, R.D. and E.K. Boggess. 1978. Ecology of coyotes in Iowa. Pages 249-265 *in* M. Bekoff, ed. Coyotes: biology, behavior, and management. Academic Press. New York, N.Y.

Table 10. Sample size, mean, standard error, and range of total body lengths (cm) for six sex-age classes of coyotes in Illinois, 1994-1997.

<u>Sex - Age Class</u>	<u>N</u>	<u>Mean</u> ¹	<u>SE</u>	<u>Range</u>
Yearling Male	26	121.9 ^a	1.1	109 - 136
Adult Male	55	121.8 ^a	0.7	109 - 132
Juvenile Male	100	120.9 ^a	0.5	112 - 130
Yearling Female	21	117.2 ^b	1.1	107 - 130
Juvenile Female	78	117.1 ^b	0.6	107 - 130
Adult Female	24	116.4 ^b	1.0	107 - 130

¹Means with different superscripts are significantly different at $\alpha = 0.05$.

Table 11. Weight/length ratios for each sex-age class of coyotes in Illinois.

<u>Sex-age class</u>	<u>N</u>	<u>Mean</u> ¹	<u>SE</u>
Juvenile female	78	0.075 ^a	0.002
Yearling female	21	0.079 ^{a,b}	0.003
Adult female	24	0.085 ^{a,b,c}	0.004
Juvenile male	99	0.089 ^{b,c,d}	0.001
Yearling male	26	0.094 ^{c,d}	0.003
Adult male	53	0.096 ^d	0.002

¹Means with different superscripts are significantly different at $\alpha = 0.05$.

Table 12. Mean kidney fat index (KFI) for each sex-age class of coyotes collected in Illinois, 1994-96. Individuals from throughout the state were lumped for analysis because no significant difference was found between northern, central, and southern regions of the state.

<u>Sex-age Class</u>	<u>N</u>	<u>Mean % KFI¹</u>
Juvenile females	115	0.56 ^a
Adult females	52	0.56 ^a
Juvenile males	133	0.55 ^a
Adult males	78	0.46 ^{a,b}
Yearling females	48	0.41 ^b
Yearling males	42	0.40 ^b

¹Means followed by different letters differ significantly at $\alpha = 0.05$.

Table 13. Sample size, mean, standard error, and range of % lipids in femur marrow of six sex-age classes of coyotes in Illinois, 1994-1997.

<u>Sex - Age Class</u>	<u>N</u>	<u>Mean</u> ¹	<u>SE</u>	<u>Range</u>
Adult Female	11	89.2	1.2	81.9-93.9
Yearling Female	17	88.1	2.8	46.2-96.9
Juvenile Female	25	87.1	1.8	51.4-94.9
Juvenile Male	35	87.3	0.8	76.2-95.6
Yearling Male	17	84.6	4.4	16.7-96.2
Adult Male	9	83.8	4.1	53.7-94.0

¹Means did not differ significantly among classes.

Fig. 1. Three regions of the state of Illinois used to investigate regional differences in coyote populations.

Fig. 2a. Age-structure for hunted coyotes in Illinois, 1994-97.

Fig. 2b. Age-structure for trapped coyotes in Illinois, 1994-97.