Reproductive Biology and Kitten Growth of Captive Bobcats in Mississippi

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Abstract: We examined 8 years of data concerning female bobcat (*Felis rufus*) reproductive characteristics and kitten growth parameters. Estrus in adults occurred in February and March, peaking in February, while yearlings cycled later (Mar to Jul). Two litters/female/year was the maximum observed, although 3 estrous cycles were observed within a single breeding season. Recycling occurred 12–14 days following kitten loss. Gestation length averaged 64 days, with parturition occurring between April and May. Litter size ranged from 1–5 kittens ($\bar{x}$ = 2.3), with a sex ratio of 1.24 M : 1 F. Mean birth mass of kittens was 150.27 g and the mean daily mass increment was 6.1% to 34.4%. Patterns of tooth eruption and morphological characteristics relative to age are summarized.

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The bobcat is internationally important as a result of the Convention on International Trade of Endangered Species of Flora and Fauna (CITES). States allowing bobcat hunting and/or trapping must assess population status and manage this species. Although the current status of the bobcat is not believed to be threatened by restrictions on international trade of other spotted cats, monitoring is necessary to detect significant changes in population levels.

Reproductive season, litter size based on corpora lutea and placental scar counts, and information on aspects of sexual maturity of the bobcat have largely been estimated based on information gathered through examination of reproductive tracts (Duke 1954, Fritts and Sealander 1978, Blankenship 1979, Parker and Smith 1983, Rolley 1983, Beeler 1985). However, several studies (Duke 1949, Gashwiler et al. 1961, Crowe 1975) have challenged the usefulness of corpora lutea counts as an index of bobcat annual reproductive success. It is difficult and often impossible

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to accurately calculate annual reproductive characteristics of bobcat populations based solely on examinations of reproductive tracts and ovaries. Therefore, it is important to have sound baseline data on litter size, estrous period, kitten growth rate, and peak breeding to relate changes in these parameters to harvest strategies, changes in habitat quality, and other human activities which may impact bobcat populations. Additionally, of the 37 species of felids in the world, 29 are similar in size to the bobcat and many are considered threatened or endangered with extinction. Our baseline data may be useful in understanding and managing the more elusive and/or rarer felid species.

Research on captive bobcats at Mississippi State University was initiated in 1981 to examine basic biological, ecological, and physiological aspects in the context of reproduction. Our objectives were to determine the reproductive characteristics and requirements of female bobcats and the growth parameters of young.

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Methods

Research Facility

Research was conducted on the Mississippi Agricultural and Forestry Experiment Stations' Blackjack Research Facility. Each bobcat was housed individually in a pen 6 x 6 x 3 m that contained ramps, tunnels, and scratching posts. Each female was provided with a wooden den 0.6 x 1 x 1 m. Pens were arranged in triplex units to facilitate efficiency and success of bobcat reproduction. Each triplex unit housed 1 male in the center with a female on either side, allowing each male to service 2 females. The facility housed an average of 21 adult bobcats per year, ranging in age from 1–12 years.

Cats were fed daily (weekdays) approximately 370 g of canned feline diet (ZuPreem®, Hills Pet Products, Inc.). On Saturdays, cats were fed a whole, intact, dead chicken to provide roughage, followed by 1 day of fasting on Sunday. Pens were cleaned daily, and cleansed with chlorine bleach weekly.

Reproductive Cycle

Date of estrus initiation and length of estrous cycle were determined by observing females daily beginning in mid-January. From mid-February through April,

or until all females had bred successfully, bobcats were monitored for estrus at dawn and dusk which reflected the bobcat's crepuscular activity pattern. A male was then placed with a female exhibiting signs of estrous behavior (e.g., increased cheek rubbing on objects, increased scent marking, loud and frequent vocalizations, tail flicking and holding the tail erect to indicate receptiveness, and interest in the male adjacently housed). The male remained housed with the female until signs of estrus or breeding were no longer observed. Dates of copulation were recorded. A female was monitored for estrous recycling if she was not successfully bred, pregnancy did not reach full term, or kittens died early (<6 weeks old).

Confirmation of pregnancy and number of fetuses were determined by laparoscopic examination performed at the College of Veterinary Medicine (CVM). Laparoscopies were conducted between 16 and 20 days since last confirmed copulation. If the procedure was conducted prior to this time, the uterine horns would appear nodulated, making it impossible to determine number of fetuses. A surgery conducted later than 20 days increased the chance of abortion or resorption of fetuses (Leopold unpubl. data). Females were anesthetized with ketamine hydrochloride (100 mg/4.5 kg) and transported to the CVM. Fetal swellings within each uterine horn were counted and recorded. Gestation length was determined by back calculating from parturition to first and last visual confirmations of copulation.

Kitten Growth

Growth rates of mother-reared kittens were recorded during 1989–1991 (VanDomelen 1992). Growth rates of hand-reared kittens were recorded during 1986–1987 (Jackson 1987). Natural logarithms were used to reflect an instantaneous growth rate rather than a finite growth rate (Caughley 1977). Instantaneous growth rates eliminate the effect of birth mass. Body measurements (mm) were recorded weekly and mass (g) was recorded daily. Kittens were sexed when first handled and confirmed once kittens were several weeks old. Birth mass was recorded for those kittens that could be safely removed from the den. Knowledge of each female's past behavior and tolerance to disturbance was used to determine how often kittens could be handled (disturbance could cause the female to kill her kittens). Additionally, extreme care was taken to minimize disturbance during breeding and gestation. Bobcats were highly susceptible to stress and disturbance at these times, possibly resulting in resorption or abortion of fetuses or killing of kittens (Leopold unpubl. data).

Body measurements included right ear length (from crown at base to tip of cartilage), neck circumference, right front limb length (from elbow), heart girth, hind foot length, tail length, and nose to rump length. Mother-reared kittens remained with the female until weaning (eating food on their own and not dependent on the mother for food, which usually occurred between 5–6 weeks postparturition), when they were removed from their mothers and housed with other kittens. Mass and heart girth measurements continued for 4–6 weeks post weaning. Additionally, other growth-related characteristics (i.e., eyes opening, tooth eruption) were documented during 1989–1990. Observations of kittens developing

independence from the female were also noted. All information is from mother-reared kittens unless otherwise noted.

Differences in birth weight of male and female kittens was tested using Student's *t*-test. Regression analysis (Minitab, Inc. 1986) using indicator variables was used to determine if differences in growth rate (mass) occurred within litter, between sexes, and between mother-reared and hand-reared kittens.

Results and Discussion

Reproductive Parameters

Experimental trials conducted at this research facility confirmed that bobcats are spontaneous ovulators (Woshner 1988). In the past it was assumed that bobcat reproduction was similar to that of the domestic cat. However, Duke (1949) suspected that there were several exceptions, including that unlike the domestic cat, the bobcat was not an induced ovulator. Subsequent research supported this observation (Crowe 1975, Fritts and Sealander 1978), although no clinical evidence existed. For several years research at this facility focused on reproductive hormone levels and mapping corpora lutea. Therefore, detection of new corpora lutea indicating ovulation was possible. Females which were housed in pens adjacent to males during the breeding season exhibited estrous behavior and ovulated. New corpora lutea were differentiated from corpora lutea of previous cycles (CLPC) via laparoscopic examination, confirming ovulation (Woshner 1988).

Initial estrous cycles occurred during February and March and peaked in the last week of February and the first 2 weeks of March (Fig. 1). Earliest initiation of estrus was 6 February and latest initiation of estrus was 27 March in females at least 2 years old. Yearling females cycled from March through June. Our research

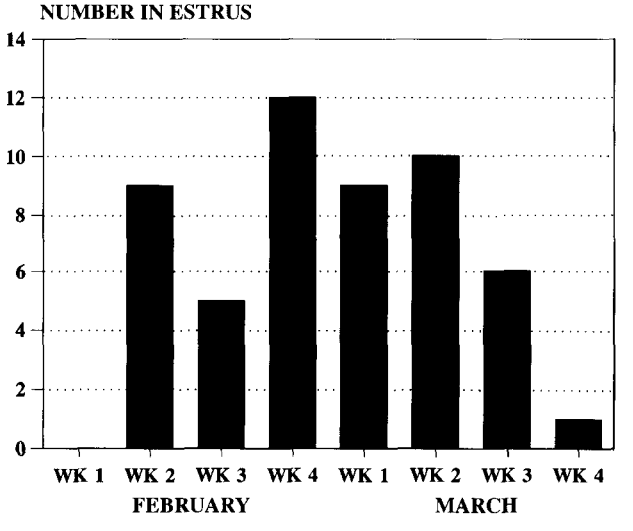

Figure 1.
Distribution of estrous cycle dates (weekly) for captive bobcats in Mississippi, 1983–1991.

confirms that yearling females are sexually mature and cycle later than females at least 2 years of age. Ovulation and pregnancy in yearling females at the research facility were confirmed via laparoscopic examination. Although yearling females bred successfully, all either resorbed the fetuses after confirmation of pregnancy or were unable to establish or maintain pregnancy until the time of the laparoscopic examination. These results would indicate that although yearling females are sexually mature and can establish pregnancy they have difficulty in maintaining the pregnancy. Due to their smaller size and higher energy expenditure for their own continued growth, yearling females may not be physically or energetically capable of maintaining a pregnancy. Eighty-five percent of all females which resorbed or aborted fetuses weighed less than 7.3 kg (4.55 to 7.27) and 77% were ≤2 years of age, indicating that both age and size appear to influence reproductive success. Another possible explanation is the lack of corpora lutea of previous cycles (CLPC) in yearling bobcats. The CLPC may play a role in the maintenance of pregnancy. If the CLPC are functional, a yearling female would lack the additional input (hormonal secretions) provided by the CLPC. Without this additional "support" the yearling female may be unable to establish or maintain pregnancy. All previous reports of yearling litter size and pregnancy rates were based on examination of corpora lutea and placental scars (Anderson 1987). It appears that placental scar counts are not very accurate for yearling females, over-estimating the number of kittens produced.

Females cycled a second or third time (estrous recycle) during a single breeding season in response to unsuccessful breeding, prevention of breeding (by not placing a male with the female), aborted or resorbed litter, or the death or removal of kittens. Females would begin to exhibit signs of estrus 12–14 days after the previous cycle, abortion or resorption, or loss of kittens. Estrous recycling occurred from March through July. The time (month) of estrous recycles was influenced by

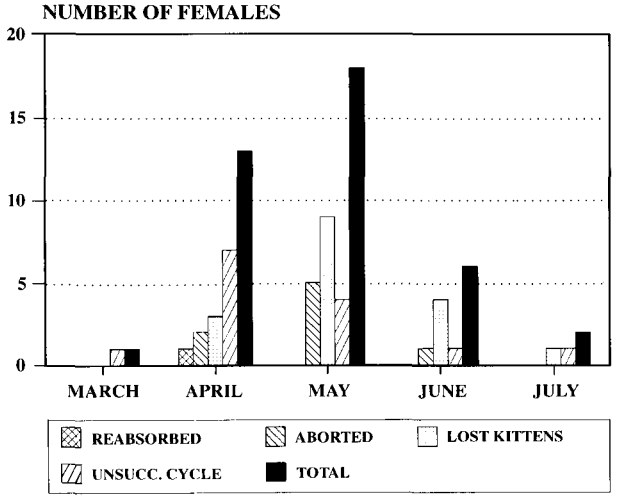

Figure 2. Total number of bobcat females in estrous recycle (monthly) and number of females in estrous recycle grouped by fate of previous estrous cycle(s) (fetal resorption, abortion, death/removal of kittens, or unsuccessful cycle/breeding attempt) in Mississippi, 1983–1990.

the fate of the previous cycle (i.e., unsuccessful breeding, abortion, resorption, or loss of kittens) (Fig. 2). Three estrous cycles (1 initial estrous cycle and 2 estrous recycles) within the same breeding season were recorded for 2 adult and 1 yearling female. One female that cycled 3 times gave birth to 2 litters. On her first estrous cycle a male was not placed with her. She recycled, bred, but lost the kittens at approximately 3 weeks of age; recycled a second time, bred and gave birth to a second litter. This confirms that bobcats can give birth to more than a single litter per year as suspected by Winegarner and Winegarner (1982). Two litters per female was the most observed within a single breeding season. However, this may be due to prevention of breeding on 1 or more of the estrous cycles, as in the previously mentioned female. Several females gave birth after each of their initial estrous cycle and first estrous recycle but were prevented from breeding on their second estrous recycle. Thus, it is possible that a female could give birth to 3 litters during a breeding season if the first 2 litters perish. Estrous recycling of a bobcat in the wild would indicate mortality of the kittens from predation or poor nutrition or that the female had not become pregnant during a previous cycle. Nevertheless, 17 September was the latest parturition date, regardless of estrous cycle (recycle) number.

Mean gestation length was 65.8 (SE = 1.9, range 62–70, N = 36) and 61.7 (SE = 2.7, range 53–60, N = 36) days from first observed copulation and last observed copulation, respectively, using data from 1983–1990. Parturition occurred from the end of April through May with the latest date of parturition for litters of initial estrous cycles 19 May. Litter size ranged from 1–5 kittens with a mean of 2.3 and 2.4 for estrous cycle and estrous recycle litters, respectively (Table 1). These mean litter sizes approximate the mean litter size (2.5) reported by Beeler (1985) using only the darkest placental scars. It would appear that the number of the darkest placental scars is the most accurate method of estimating *in utero* litter size. However, this method should be used cautiously when estimating yearling pregnancy rates. Number of kittens and number of fetuses were the same for all

Table 1. Number and frequency of litter size for initial estrous cycle litters and subsequent estrous cycle (recycle) litters for captive bobcats in Mississippi, 1983–1990.

	Estrous			
	Initial		Recycle	
Litter size	*N*	%	*N*	%
1	5	20.0	7	31.8
2	11	44.0	4	18.2
3	5	20.0	8	36.4
4	4	16.0	2	9.1
5	0	0.0	1	4.5

litters, with the exception of 2 females. Female Number 8 and female Number 24 (mother and daughter) repeatedly gave birth to 1 less kitten than the observed number of fetuses (Jackson 1987). Sex ratio (M:F) for kittens was 1.24:1 and 1.17:1 for estrous cycle and estrous recycle, respectively.

The high density of bobcats at the research facility did not have an effect on reproductive success. The only occurrence of density influencing reproductive success was when 2 females were housed together. Woshner (1988) found that only 1 of 2 females housed together during the breeding season went through an estrous cycle. The female which cycled also appeared to be the behaviorally dominant of the 2. However, the roles of the 2 females while still housed together later reversed and the female which had not previously cycled went through an estrous cycle. Litter sizes were not influenced by the high density of bobcats. The litter sizes were similar to those summarized by Anderson (1987) for wild bobcats.

As previously mentioned, some of the bobcats wee highly susceptible to stress-related abortions, resorptions, or killing of kittens. In almost all instances the cause of the abortion or resorption was determined. Several abortions were caused by a tractor mowing grass immediately outside the research facility. The abortions coincided with the first mowing of spring. One female accidentally killed her kittens as a result of stray dogs outside the facility. In attempting to carry her kittens to a new, "safer" location, she became very stressed and careless, killing her kittens by dropping and banging them against the walls. There does appear to be a period when the bobcats are most susceptible to abortions, with 71% of the abortions occurring between days 24 and 29 of pregnancy. Although the causes of the stress-related abortions, resorptions, and killing of kittens were influenced by the captive surroundings, these results indicate that stress (e.g., human encroachment, poor diet) may influence the bobcats reproductive success and will most likely have an impact during the fourth week of pregnancy.

Kitten Growth Parameters

Mass and body measurements of mother-reared kittens were recorded for 6 litters (14 kittens) in 1989, 6 litters (16 kittens) in 1990, and 6 litters (17 kittens) in 1991 (Table 2). Mass and body measurements of hand-reared kittens were recorded for 5 males and 4 females (Table 2). Mean birth mass was 150.27 g (N = 40, SD = 23.2). Adult female body mass and litter size were not correlated with mean birth mass, which indicates there are additional factors (i.e., nutrition, genetics) influencing kitten birth mass (VanDomelen 1992). Bobcat kitten birth mass fits Hemmer's (1974) negative allometric relationship between body mass of adult females and body mass of young at birth (mass at birth = 0.23 x adult mass$^{0.72}$). This equation would yield a birth mass of 150.87 g for an average adult female bobcat weighing 8.2 kg. We found a high degree of variation in kitten growth across and within litters. Of 18 litters on which growth measurements were taken (1989–1991) 15 litters (83%) had at least 1 kitten gaining weight at a significantly different rate ($P < 0.05$) from at least 1 other kitten. Mean rate of increase of the kittens' body mass fluctuated between 6.1% and 34.4% for the first 11 weeks. Male and female kitten growth rates were not significantly different ($P = 0.7557$).

Table 2. Mean weekly mass (g) of mother-reared and hand-reared (Jackson 1987) bobcat kittens in Mississippi, with sample sizes and standard deviations provided.

	Mother-reared						Hand-reared			
	Male			Female			Male ($N = 5$)		Female ($N = 4$)	
Age	$\bar{x}$	N	SD	$\bar{x}$	N	SD	$\bar{x}$	SD	$\bar{x}$	SD
0	155	14	18	155	14	15	124		135	
1	219	21	60	206	21	63	293	103	343	126
2	304	19	106	283	19	96	325	87	394	120
3	410	20	138	347	20	134	426	112	483	163
4	489	19	174	441	19	170	555	111	581	181
5	580	18	204	537	19	213	699	119	708	239
6	661	16	248	626	16	242	827	146	873	318
7	835	17	271	694	14	269	1,106	152	1,096	411
8	969	12	376	877	10	297	1,362	131	1,327	366
9	1,077	11	368	1,062	14	344	1,677	186	1,632	308
10	1,353	10	329	1,129	6	449	1,952	152	1,838	413
11	1,432	6	415	1,523	3	254	2,162	246	2,015	476

Table 3. Mean body measurements (mm) of captive-born kittens[a] in Mississippi, summarized by week, 1989–1991 (numbers in parentheses give MSE).

	Week							
	0	1	2	3	4	5	6	7
Ear	5.7	7.0	8.1	9.2	14.7	18.5	20.0	29.1
	(3.9)	(4.3)	(5.4)	(7.5)	(10.1)	(12.7)	(14.6)	(12.0)
Neck	69.9	96.9	96.4	106.4	115.2	119.3		122.6
	(35.0)	(12.4)	(27.7)	(14.8)	(18.5)	(19.0)		(7.4)
Hrtgrt[b]	114.2	124.6	131.9	142.4	152.0	158.0	161.8	169.8
	(10.2)	(11.8)	(16.4)	(18.0)	(19.9)	(22.6)	(24.8)	(24.6)
Frtleg[c]	57.4	63.9	70.5	78.3	86.3	94.3	101.3	109.9
	(2.9)	(5.5)	(5.7)	(8.4)	(7.8)	(10.5)	(11.4)	(7.0)
Hndft[d]	36.7	41.4	46.8	50.5	57.5	63.5	70.2	74.9
	(2.1)	(2.6)	(3.9)	(13.3)	(6.7)	(8.1)	(9.7)	(6.7)
Tail	31.8	30.9	31.9	35.2	42.0	41.2	46.1	50.1
	(3.4)	(3.1)	(8.1)	(9.0)	(5.1)	(12.5)	(6.6)	(5.9)
Total	189.6	209.7	228.1	252.8	269.6	275.6	303.6	324.6
	(9.7)	(9.7)	(13.6)	(22.3)	(25.2)	(27.7)	(30.9)	(23.3)

[a] Mean taken from 18 litters.
[b] Heart girth.
[c] Front leg.
[d] Hind foot.

Table 4. Characteristics of captive-born kittens from birth to weaning, 1983–1990, Mississippi.

	Mean	Range	SD	*N*
Age (days) when:				
Eyes begin to open	13.2	9–16	2.2	20
Eyes completely open	16.8	15–18	1.0	12
Initial tooth eruption				
Upper incisor	15.8	11–19	2.8	11
Lower incisor	17.0	9–20	3.9	13
Upper canine	15.8	10–22	4.3	16
Lower canine	16.3	10–20	4.8	12
Begin eating solid food	41.7	37–45	2.9	7 Litters
Emerging from den	37.8	33–42	3.5	6 Litters

Rate of increase (mass) of mother-reared bobcat kittens and hand-reared bobcat kittens (Jackson 1987) were not significantly different ($P = 0.1352$). Kitten growth pattern over time (week) was not significant ($P = 0.1335$). A growth chart was formulated for each body measurement (Table 3). The range of days when the eyes begin to open and are completely open fall within the range previously reported by Jackson et al. (1989) on hand-reared bobcat kittens. Kittens started eating solid food shortly after they began emerging from the den (Table 4). Tooth eruption patterns were similar to that measured on hand-reared kittens (Jackson 1988) (Table 4).

Summary

Reproductive success and rate of increase are important indices of total population health (Caughley 1977). Merson and Kirkpatrick (1981) found that reproductive activity in white-footed mice (*Peromyscus leucopus*) was more sensitive to minor food restrictions than body mass or amount of carcass fat. They concluded that reproductive characteristics are better indicators of recent food availability than body mass or carcass fat. Variation of reproductive activity in wild populations may indicate above or below average habitat quality and population health.

This database for captive bobcats agrees closely with patterns reported for free-ranging bobcats (Anderson 1987). Information gained from research using captive bobcats may be comparable to that from wild, free-ranging bobcats. The baseline values provided can serve as a guide for assessing female reproductive activities, reproductive success, and could be used by modelers of bobcat growth and energetics.

Literature Cited

Anderson, E. M. 1987. A critical view and annotated bibliography of literature on bobcat. Spec. Rep. No. 62. Colo. Div. Wildl. 61pp.

Beeler, I. E. 1985. Reproductive characteristics of captive and wild female bobcats (*Felis rufus*) in Mississippi. M.S. Thesis, Miss. State Univ., Mississippi State. 81pp.

Blankenship, T. L. 1979. Reproduction and population dynamics of the bobcat in Texas. M.S. Thesis, Texas A&M Univ., College Station. 53pp.

Caughley, G. 1977. Analysis of vertebrate populations. 2nd Ed. John Wiley & Sons. New York, N.Y. 234pp.

Crowe, D. M. 1975. Aspects of aging, growth, and reproduction of bobcats from Wyoming. J. Mammal. 56:177–198.

Duke, K. L. 1949. Some notes on the histology of the ovary of the bobcat (*Lynx rufus*) with special reference to the corpora lutea. Anatomical Record 103:111–132.

———. 1954. Reproduction in the bobcat *Lynx rufus*. Anatomical Record 120:816–817.

Fritts, S. H. and J. A. Sealander. 1978. Diets of bobcats in Arkansas with special reference to age and sex differences. J. Wildl. Manage. 42:533–539.

Gashwiler, J. S., W. L. Robinette, and O. W. Morris. 1961. Breeding habits of bobcats in Utah. J. Mammal. 42:76–84.

Hemmer, H. 1974. Gestation period and postnatal development in felids. Pages 90–100 *in* R. L. Eaton, ed. The world's cat III: Biology, ecology, behavior, and evolution. Carnivore Res. Inst., Burke Museum, Univ. Washington, Seattle.

Jackson, D. L. 1987. Growth and development of captive bobcats (*Felis rufus*). M.S. Thesis, Miss. State Univ., Mississippi State. 63pp.

———. 1988. Dental eruption in bobcats. J. Wildl. Manage. 52:515–517.

———, E. A. Gluesing, H. A. Jacobson, and B. D. Leopold. 1989. Anatomical development of captive bobcats in Mississippi. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 43:460–465.

Merson, M. H. and R. L. Kirkpatrick. 1981. Relative sensitivity of reproductive activity and body-fat level to food restriction in white-footed mice. Am. Midl. Nat. 106:305–312.

Minitab, Inc. 1986. Minitab reference manual. 2nd ed. Minitab, Inc., State College, Pa. 266pp.

Parker, G. R. and G. E. Smith. 1983, Sex- and age-specific reproductive and physical parameters of the bobcat (*Lynx rufus*) on Cape Breton Island, Nova Scotia. Can J. Zool. 61:1771–1782.

Rolley, R. E. 1983. Behavior and population dynamics of bobcats in Oklahoma. Ph.D. Diss., Okla. State Univ., Stillwater, 98pp.

VanDomelen, E. D. 1992. Nutrition, prey assimilation, and bioenergetics of captive bobcats. M. S. Thesis, Miss. State Univ., Mississippi State. 144pp.

Winegarner, C. E. and M. S. Winegarner. 1982. Reproductive history of a bobcat. J. Mammal. 63:680–682.

Woshner, V. M. 1988. Aspects of reproductive physiology and luteal function in the female bobcat (*Felis rufus*). M.S. Thesis, Miss. State Univ., Mississippi State. 65pp.