PRODUCTIVITY AND MORTALITY OF GRAY FOXES AND RACCOONS IN SOUTHWESTERN WISCONSIN

by

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FOREWARD

My thesis is prepared as a series of 4 technical papers for publication in the Journal of Wildlife Management.

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RH: Productivity and Mortality of Gray Foxes • Root

PRODUCTIVITY AND MORTALITY OF GRAY FOXES IN SOUTHWESTERN WISCONSIN

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Abstract: Age-specific, sex-specific, and mean annual mortality and reproductive rates were gathered from 846 gray fox (*Urocyon cinereoargenteus*) carcasses and pelts collected in southwestern Wisconsin from 26 October through 31 January 1978-80. Litters averaged 3.4 young for 81% of 54 yearlings and 3.6 for 98% of 42 older adults. Testes weights and sperm smears indicate that all males are reproductively active by late January, although adults begin to produce mature sperm earlier in the year than juveniles. The sex ratio of the harvest (92M:100F) did not differ ($P > 0{,}05$) from an equal sex ratio, in contrast to reports of significantly more males harvested in late fall collections. The harvest consisted of 66% juveniles, 19% yearlings, and 15% older adults. Maximum longevity approached 6.5 years although few gray foxes (3%) survive more than 4.5 years of life. Age structure data obtained from carcasses from furbuyers must be treated cautiously because foxes trapped and sold unpelted to fur houses were significantly younger ($P < 0.10$) than those collected from trappers who pelt their own catch. Known mortality included trapping (59%), hunting (32%), and vehicle kills (9%). Most of the harvest (55%) occurred during November, with 30% in December and 14% in January. The net reproductive value (0.76) indicated that the gray fox population of southwestern Wisconsin was declining during this study. Management recommendations include (1) a shortened trapping season from 1 November - 31 December, (2) a hunting season running from 1 December - 31 January, and (3) mandatory registration of gray fox pelts with a tyvac tagging program.

J. WILDL. MANAGE.

Key words: age structure, gray foxes, harvest, management recommendations, mortality, productivity, reproduction, southwestern Wisconsin, *Urocyon cinereoargenteus*.

Although extensive red fox (*Vulpes vulpes*) research has been conducted in recent years (e.g. Storm et al. 1976, Johnson and Sargeant 1977), comparably fewer gray fox studies are available. Most gray fox research conducted during the 1950's determined general aging techniques (Sullivan and Haugen 1956, Wood 1958, Lord 1961), reproduction (Layne and McKeon 1956, Sullivan 1956, Wood 1958), and population levels (Wood 1959, Lord 1961). More recent studies have dealt with food habits (Yoho and Henry 1972, Pils and Klimstra 1975, hensley 1977), diseases (Monson and Stone 1976), and parasites (Monson et al. 1973, Stone et al. 1974), Stone 1974, Zeh et al. 1977, Jessup 1979). Except for studies of gray fox reproduction and movements in Alabama (E. Hill, Mississippi State Wildl. Coop., pers. commun.), and the effects of intensive gray fox control on population dynamics of rodents and sympatric carnivores (Hensley and Fisher 1975), no extensive gray fox productivity and mortality research has been initiated in the past 20 years.

In Wisconsin, Richards and Hine (1953) studied the effects of bounties, population trends, and food habits on red foxes and gray foxes from 1946-50, but were limited by inadequate aging techniques and small sample sizes of gray foxes. Besadny (1966) analyzed the stomach contents of only 13 gray foxes collected from 1955-65. Petersen et al. (1977) evaluated the current gray fox hunting and trapping season in Wisconsin, and indicated that the once fairly common population of the upper Mississippi River Valley has been virtually eliminated during the past 25 years. The state population in 1975 was estimated at only 3,000 to 4,000 gray foxes (Petersen et al. 1977), with 2,303 (50%) harvested that fall and winter (Wisconsin Dep. Nat. Resour. 1980). Overexploitation of gray foxes was attributed to increased demand created by pelt values reaching an average of $19.38 during 1975-76 (Petersen et al. 1977).

As long as fox fur remains in vogue, the high demand for gray foxes has the potential to depress the Wisconsin population (Petersen et al. 1977), possibly to where productivity no longer balances mortality. The objectives of this study were to determine age-specific, sex-specific, and mean annual mortality and reproductive rates of gray foxes in southwestern Wisconsin.

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STUDY AREA

Gray fox carcasses were collected within a 13-county region of southwestern Wisconsin (Fig. 1). This area is characterized by open hills and broad ridges in southern areas, to deeply incised valleys and narrow ridges in the north (Hole 1977). Predominate vegetation types consist of white oak (Quercus alba), red oak (Q. rubra), black oak (Q. velutina), shagbark hickory (Carya ovata), white ash (Fraxinus americana), green ash (F. pennsylvanica), and maple-basswood (Acer spp. - Tilia americana) associations (Curtis

1959) interspersed with small farms on ridge tops and valley floors. The combination of forested and cropped land creates a great amount of edge which seems essential for higher gray fox densities in southwestern Wisconsin (Petersen et al. 1977).

METHODS

From 26 October - 31 January 1978-80, 636 gray fox carcasses and 210 pelts (about 9% of statewide harvest) were collected from 104 trappers, hunters, and furbuyers throughout southwestern Wisconsin. Upper mandibles and reproductive organs were removed from each carcass, and stored frozen for 2 to 3 months before analysis, and after sex, date of capture, cause of death, and county of kill were recorded; pelts were examined for sex ratio information.

Uteri of adult vixens were stained with acidified potassium ferrocyanide (Larson 1967) to re-define degenerating placental scars (Layne and McKeon 1956, Sullivan 1956), and litter sizes calculated from counts of prussian blue colored scars. Ovaries were macroscopically sectioned (Pimlott and Mossman 1959) and analyzed for corpora albicantia and corpora lutea (Cook 1977).

Male testes with attached epididymides were weighed to the nearest 0.1g, and fluid from 1 cauda epididymis examined microscopically for the presence of mature spermatozoa. To reduce the bias caused by body size differences, the average weight of each animal's testes (g) was divided by the greatest skull length (mm) and multiplied by 100 (Payne et al. 1966, Gipson et al. 1975).

Age was determined by the presence of canine root apical foramina, pulp cavity measurements, and cementum annuli counts (Root 1981). All gray foxes aged at ≥1.5 years were designated as adults; foxes <1.5 years as juveniles; and those aged at 1.5 years old as yearlings. Barren adults refer to vixens that produced no young, either through failure to mate, failure of eggs to be fertilized, or loss of the embryos prior to implantation or shortly thereafter, and showing no evidence of pregnancy or placental scars in the uterine horns (Layne and McKeon 1956).

RESULTS AND DISCUSSION

Reproduction

The number of placental scars affords the best estimate of litter size generally available for late fall and early winter killed vixens (Layne 1958); however, the method provides somewhat inaccurate estimates if potential sources of error are not considered. Sheldon (1949) used only dark pigmented scars for litter size determination; Englund (1970) defined 6 distinct color shades of red fox uterine scars, and concluded that only the darker shades represented the remnants of actual births. Lighter colored scars indicated embryos dying in utero, or suspected pregnancies of earlier years. Placental scar data provide slightly biased estimates of actual natality through the inclusion of sites where resorptions occurred but were indistinguishable in postpartum uteri (Layne 1958). Total prenatal mortality of gray foxes varies between 15% and 32% (Gier 1947, Layne and McKeon 1956, Layne 1958).

Uteri of 96 adult vixens were collected during this study.

One female was eliminated from the sample because she had 1 distinct placental scar although she was aged as a juvenile. Pils and Martin (1978) reported that Englund (pers. commun.) observed no placental scars from 1,000 juvenile vixen red foxes; however, S. H. Allen (North Dakota Fish and Game Comm., pers. commun.) and C. M. Pils (Wisconsin Dep. Nat. Resour., pers. commun.) have noted placental scars when examining the uteri of juvenile red foxes from North Dakota and Wisconsin, respectively.

Barren Females

Previous studies of wild gray foxes have suggested that the majority of vixens breed in their 1st year (Layne and McKeon 1956, Wood 1958). This belief was based on the fact that the proportion of barren adult females was not high enough to indicate a low level of successful matings in a particular age class. In New York, Layne and McKeon (1956) and Sheldon (1949) noted that only 3.8% (N=53) and 3.3% (N=90) of the adults were barren, respectively. Wood (1958) concluded that only 6.4% of 141 female gray foxes from Georgia and Florida were unsuccessful breeders.

In southwestern Wisconsin, 12% of 96 vixens were barren (Table 1); however, 10 of the 11 barren females were aged as yearlings, and only 1 (9%) was an older adult. Overall, 19% of 54 yearlings and only 2% of 42 older adults were barren.

This high incidence of barren yearling gray foxes may be related to a complete deterioration of scars in yearling female reproductive tracts. Layne and McKeon (1956) and Sullivan (1956) indicated that placental scar counts are reliable indicators of litter size only through October; however, redifferentiation of degenerating scars with acidified potassium ferrocyanide should have eliminated this problem (Larson 1967).

Extensive studies on breeding silver foxes (V. vulpes) in fur farms (e.g. Johansson 1938, 1941, Pearson and Bassett 1946, Starkov 1949) have shown that captive yearling vixens are less dependable breeders than older vixens because the percentage of unmated females, sterile matings, and abortions are much higher in yearlings than the older age groups. Harris (1979) concluded that the higher incidence of barren yearling red foxes (52% of the age class) possibly was related to some physiological "immaturity". The poor breeding performance of yearling vixen arctic foxes (Alopex lagopus) was caused by an increased percentage not ovulating in comparison to the older age groups (Aamdal and Fougner 1973), and early embryonic death was an important factor in the reduced productivity of yearling vixens (Fougner 1972).

Englund (1970) found a good correlation between productivity and food availability, and concluded that in years of poor food supply there was a high incidence of barren first-year red foxes. But, in general, studies in areas where environmental factors remain relatively constant from 1 year to the next have shown a high percentage of successful matings (e.g. Sheldon 1949, Layne and McKeon 1956).

Layne and McKeon (1956) collected female gray fox reproductive tracts after the breeding season that contained corpora lutea but showed no evidence of pregnancy or placental scars, indicating that some females may reach puberty too late in the season for successful matings. Male gray foxes attain sexual maturity at an earlier age than females (Layne 1958), and produce sperm only through March (Follman 1978). If female gray foxes exhibit a reproductive cycle similar to red foxes, juveniles come into heat about 2 weeks later than adults (Pearson and Bassett 1946) and remain in estrus <1 week (Johansson 1938, Enders 1938, Asdell 1964). Possibly a small percentage of juvenile female gray foxes are not reproductively active during the height of the mating season, and are unsuccessful breeders until their 2nd year of life. Layne (1958) examined a juvenile collected in June that had well-developed corpora lutea in the ovaries although the uterus was virginal in appearance.

Litter Size

Mean litter size estimates of gray foxes have ranged from 3.3 to 5.2 young for several regions of the country (Table 2). In southwestern Wisconsin, placental scar counts of 85 vixens averaged 3.5 young, with a range of 1 to 9 scars and a mode of 4 (Fig. 2). Richards and Hine (1953) reported an average of 3.9 young per female gray fox (N=44) from southern Wisconsin. Only Lord (1961) reported a smaller mean litter size than litter numbers determined during this investigation.

The lower mean litter size reported for southwestern Wisconsin may reflect a wider range of environmental and nutritional conditions affecting this sample, on the northern periphery of its range (Hall and Kelson 1959, Petersen et al.

1977). Englund (1970) found a good relationship between birth litter size and food availability for red foxes from Sweden; Ryan (1976) suspected that nutritional and environmental factors contributed to lower mean litter sizes for red foxes from New South Wales.

Mean birth litter size of female gray foxes from southwestern Wisconsin remained fairly constant from 3.41 to 3.38 through 2.5 years of life. Beyond that, litter sizes increased slightly but differences between separate means were not significant ($\underline{P} > 0.05$). Senescence may affect productivity of 4.5+ year old gray foxes, but sample sizes from my collections are too small to be conclusive. Harris (1979) concluded that old age significantly decreased litter size of wild London red foxes by the 5th to 6th breeding season. Allen (1975) suggested that litter sizes of North Dakota red foxes decline after 4 years of life. Age did not affect reproduction of ranch raised silver foxes or blue foxes (*A. lagopus*) before 8 to 10 years (Starkov 1949).

Ovarian Analysis

Only 1 vixen gray fox inspected from southwestern Wisconsin possessed corpora lutea, because corpora lutea occur in the ovary during pregnancy, when few foxes were harvested. Two corpora lutea were clearly evident in each ovary. Gier (1947) in Ohio and Layne and McKeon (1956) in New York reported an average of 5.2 corpora lutea. Layne (1958) found an average of 4.4 corpora lutea per vixen from southern Illinois.

Corpora albicantia counts for southwestern Wisconsin vixens were an unreliable indicator of ova production. Fifty percent of 96 adults examined showed no evidence of corpora albicantia although uterine placental scars were clearly evident. An additional 25% of the remaining 48 vixens that were examined possessed fewer albicantia than placental scars.

Cook (1977) indicated that some albicantia persist for more than 1.5 years in vixen gray foxes from Georgia; however, my results agree with Sullivan (1956) and Layne and McKeon (1956) who concluded that ovarian analysis was unreliable past October due to the degeneration of corpora albicantia.

Male Reproduction

The percentage of males with mature spermatozoa in the cauda epididymis increased from November to January (Table 3). During January all 20 males examined had sperm and were considered reproductively active. More adult males than juveniles possessed mature sperm in November and December but the sample sizes were too small for statistical comparison. My investigations of epididymides agreed with Follman (1978) who concluded that adult males produce sperm earlier in the year than juveniles in Illinois.

Onset of breeding activity in the male gray fox was accompanied by an increase in testes weight (Fig. 3). Juveniles showed a similar rate of increase in testes weight as adults.

Sex Ratios

Past studies have estimated sex ratios from samples of fetuses, pups at dens, and foxes taken by trappers and hunters. Spring and summer tallies of foxes shot and trapped generally indicate a nearly equal sex ratio, or one favoring males (Layne and McKeon 1956, Sullivan 1956, Wood 1958, Layne 1958). Foxes shot or trapped in the fall and winter predominately favor males (Layne and McKeon 1956, Linhart 1959, Oleyar and McGinnes 1974) due to their greater mobility and subsequent susceptibility to hunting and trapping pressure (Sheldon 1949). Fetal sex ratios also favor males (Sheldon 1949, Layne and McKeon 1956, Layne 1958).

The overall sex ratio of 846 gray foxes harvested in southwestern Wisconsin did not depart significantly ($\underline{P} > 0.05$) from an assumed 50:50 ratio (92M:100F), in contrast to reports of significantly ($\underline{P} < 0.05$) more males expected in collections during the late fall (Sheldon 1949, Layne and McKeon 1956, Linhart 1959). Sex ratios did not differ in relation to age (Fig. 4) or method of capture (Fig. 5, $\underline{P} > 0.05$); however, there was a tendency towards fewer juvenile males per female from November to January, and more females than males were trapped than shot during the entire period. If males harvested during the late fall and early winter actually are more vulnerable to capture, then the southwestern Wisconsin sex ratio may favor females more than my overall sex ratio would indicate. Once the more vulnerable males are harvested during November (Fig. 4), sex ratios apparently favor females, although these differences were not significant ($\underline{P} > 0.05$).

Harvest

Kinds and Timing

Causes of death were assigned to 547 of 636 gray foxes collected during the 1978-79 and 1979-80 trapping season

(3 November - 31 January). Only 1 cause, such as "shot" or "trapped" was assigned to each animal; however, I recognize that mortality can be the result of many contributing factors (Errington 1963, Davis 1970, Storm et al. 1976).

The 2 most common causes of death were trapping (59%) and hunting (32%, Fig. 6). Peak harvest occurred during November (Fig. 7) when over 55% of the harvested gray foxes were taken, as compared to 30% in December and 14% in January. Nearly equal numbers of both sexes were collected each month by each method of capture (Fig. 8).

Trappers and hunters had their greatest impact in November, when they harvested 34% and 17% of the total kill, respectively. Only 8% of the 92 foxes shot in November were harvested during the first 2 weeks. Most of the foxes harvested in early November were trapped ($\underline{X}^2$=69.06, $\underline{P}$ $<$0.005, 1 df, N=92, Fig. 8). The higher percentage of foxes shot in late November (92%) probably results from increased harvest pressure during the annual Wisconsin gun white-tailed deer (_Odocoileus virginianus_) season incorporating over 600,000 hunters, which runs for 9 days during late November. Most fox trapping occurs early in the season before the ground freezes and dirt hole, scent post, mound, and other sets become difficult to construct and maintain.

Miscellaneous Mortality

Reported vehicle kills were highest in November (58%) although many probably were killed earlier in the year. One male gray fox reported to have been killed by a vehicle in November was extremely small and had deciduous dentition, indicating an actual kill date of at least 1 month earlier (Wood 1958), unless the fox was from an unusually late litter.

The overall reported proportion of vehicle kills (9%) is probably an underestimate because pelts are not valuable (V. Dobbs, furbuyer, pers. commun.), and some foxes hit by cars land in ditches out of view (Storm et al. 1976).

One of the 2 male gray fox carcasses collected during this study may have died from tularemia; however, confirmation was difficult due to decomposition of the carcass. The cause of death of the other male could not be determined.

Although mange is a controlling influence on some red fox populations (Trainer and Hale 1969, Zeh 1974), it has not occurred often in gray foxes (Stone et al. 1974). No mangy gray foxes were reported by cooperating furbuyers, trappers, hunters, and none of the 846 gray fox pelts I observed showed evidence of mange.

Age Structure

Of the 636 gray foxes aged, 66% were harvested in their 1st year of life, and 85% (596) were under 2.5 years of age (Fig. 9). Only 3% (20) of the harvest was over 4.5 years of age, which agrees closely with the data of Wood (1958). Although potential longevity is 14 or more years, captives rarely attain 8 years of age, and few gray foxes survive 6 years in the wild (Jackson 1961).

The percentage of juveniles in the southwestern Wisconsin harvest (66%) agrees with reports of 69% juveniles in southern Wisconsin (Richards and Hine 1953) and 61% in Florida and Georgia

(Wood 1958); however, the extension of an age structure determined from carcass collections to represent the living population must be done cautiously. A comparison of the age structure of animals taken and pelted by trappers versus those gray foxes trapped and sold unpelted to furbuyers in southwestern Wisconsin (Table 4) indicated a signficant ($\underline{X}^2$=3.04, $\underline{P}$ <0.10,1 df, $\underline{N}$=243) preponderance catch of juveniles with carcass collections from fur houses. Because much of the age structure data reported in the literature are determined from samples collected at fur houses they may be biased towards juveniles to an unknown degree. In southwestern Wisconsin, trappers who pelt their own catch were harvesting significantly more adults (41% of total harvest) than those selling their unpelted catch to fur houses (33.7% of total harvest), probably because the latter are less skilled trappers who take a greater proportion of inexperienced juvenile gray foxes. Therefore, a more accurate representation of the actual age structure of the harvest must be made by collecting carcasses from furbuyers and those individuals who pelt their own catch.

Mortality

The age distribution of the sample (Fig. 9) was assumed to represent that of the living population, and was treated as an "1_x" series (Caughley 1966, Seber 1973). Life table analysis indicated that total annual mortality of gray foxes was 66% (Table 5). Mortality was 72% for young-of-the-year, and then remained fairly constant from 51% to 65% for the next 3 years. Beyond that, sample sizes were too small to be conclusive. The survival curve (Fig. 10) resembles the type II curve for species assumed to have relatively constant survival throughout life (Boughey 1973).

Population Stability

The net reproductive rate, R_o (Odum 1971), was calculated from the female data (Table 1 and Fig. 9) to gain an indication of the stability of the population during this study. If an equal sex ratio at birth is assumed, and the mean number of young per female (Table 1) accurately represents the productivity of vixens from southwestern Wisconsin, the replacement rate for both years combined was 0.76 (Table 6). Since an R_o value of 1.0 means the population is replacing itself every generation, these results indicate that the gray fox population of southwestern Wisconsin was declining during this study.

MANAGEMENT RECOMMENDATIONS

The wildlife management plan of the Wisconsin Department of Natural Resources requires the creation and implementation of regulations to make optimum use of furbearers from biological, recreational, and economic standpoints. Every effort should be made to design regulations that maintain desirable population levels from year to year (Pils and Martin 1978).

Because my analysis of gray fox reproduction and mortality indicates that the southwestern Wisconsin population is declining, and Petersen et al. (1977) concluded that gray fox densities in Wisconsin are extremely low, management should be directed towards reducing the statewide harvest of gray foxes. However, this may be unnecessary if pelt values for gray foxes continue to decline. Petersen et al. (1977) found a significant correlation ($\underline{P} < 0.01$) between pelt prices and the estimated annual purchase of gray fox pelts from Wisconsin, and concluded that a decrease in the dollar value of gray fox pelts would cause a reduction in the harvest. But, because pelt prices fluctuate in relation to changing market conditions, they are an unreliable technique for effectively managing the Wisconsin gray fox population. The following recommendations should be considered.

Harvest Regulation Changes

The Wisconsin gray fox harvest is influenced greatly by the demand for red foxes and raccoons (Procyon lotor), which has increased substantially due to recent high pelt values for long-haired furbearers. Gray foxes in Wisconsin are harvested incidental to red foxes and raccoons, with about 65% of the trappers and 80% of the hunters harvesting only 1 gray fox during an entire season (Petersen et al. 1977). Modification of harvest regulations for red foxes and raccoons may influence gray fox populations (Petersen et al. 1977), but I think that shortening the current raccoon season would have little direct effect on reducing the harvest of gray foxes. The raccoon season in Wisconsin normally opens about 2 weeks earlier (about 15 October) than that for red foxes and gray foxes (about 1 November). The few gray foxes harvested illegally in the state during the October raccoon season probably would not result in substantial reduction in the annual harvest of gray foxes.

A more feasible management procedure for gray foxes involves initiating a shortened, split season for trappers and hunters. The present gray fox hunting and trapping season extends from about 1 November - 31 January; the revised trapping season would run from 1 November - 31 December. The primary objective of this alteration would be to reduce mortality by eliminating January from the season (about 14% of the annual harvest were trapped during January (Fig. 7)), and decrease the harvest of poor quality or rubbed pelts which have lower economic value (V. Dobbs, furbuyer, pers. commun.).

The gray fox hunting season could be shortened to run from 1 December - 31 January. My data on gray fox mortality indicates that, in November, hunters took 17% of the annual harvest in southwestern Wisconsin (Fig. 7), of which 92% were shot during the gun deer season of late November. Apparently few individuals specifically hunt gray foxes in November. In addition, delayed opening of the hunting season would reduce the crippling loss due to inadequate snow cover and poor tracking conditions during November.

Split season harvests for hunters and trappers are practiced in Illinois, Indiana, and Missouri, and may provide a means of minimizing the difference of opinion that exists between fox hunters and trappers. Each group believes the other is harvesting a disproportionately higher share of the red fox and gray fox population (Petersen et al. 1977). Season changes can be made through routine administrative procedures, and would cost little.

However, enforcement problems could be substantial. In Iowa, some trappers still took foxes in traps supposedly set for coyotes (*Canis latrans*), raccoons, skunks (*Mephitis mephitis*), or badgers (*Taxidea taxus*) when the trapping season was closed (Andrews 1977). These foxes were not being released alive, or they were shot upon release and bagged as a hunted fox because the hunting season was still open. Conservation officers found that the illegal harvesting of foxes by trappers after the season closed was nearly unenforceable. Iowa finally returned to a concurrent hunting and trapping season in 1977. Unless these enforcement problems can be minimized or eliminated, Wisconsin will face a similar enforcement dilemma.

Population Monitoring

Pils and Martin (1978) suggested that the accuracy of the current furbearer abundance indices in Wisconsin (fur harvest reports) are questionable. Some furbuyers do not separate gray foxes from red foxes in their records, but estimate the number of gray foxes they purchased at about 20% of the total number of foxes they purchased that year (Petersen et al. 1977). Others sell the gray foxes they purchase to other furbuyers, but both individuals report the animals when filing their reports, thus inflating the actual harvest in the state (C. M. Pils, Wisconsin Dept. Nat. Resour., pers. commun.). Because reliable data regarding the harvest of gray foxes in Wisconsin can provide important information for future management decisions, management should consider initiating a mandatory pelt tagging program for all gray foxes harvested in Wisconsin. Trappers and hunters in Wisconsin would be required to obtain plastic tyvac carcass tags from their local game warden, attach 1 tag through the gambrel of a hind leg of each gray fox they harvest, and seal and tie with the string incorporated as a backup system similar to the method used in 1980-81 with archery-killed deer. The hunter or trapper would then validate the pelt tag by cutting out notches indicating the sex, month of capture, method of harvest, and county of kill. Legally tagged foxes then would be brought to a local game warden on the dates each month that bobcat (*Lynx rufus*), otter (*Lutra canadensis*), and beaver (*Castor canadensis*) are tagged, and the warden would remove the tyvac tag and replace it with a pelt registration tag. This tyvac tagging program would supply valuable information on (1) the actual numerical harvest of gray foxes in the state, and (2) base line data on sex ratios, harvest methods, and locations of kills, which could be used to monitor the population and influence future management decisions. If successful, this program could be expanded to include other species for which harvest information is desirable, most notably, bobcats and otters.

FUTURE RESEARCH

My analysis of the productivity and mortality of gray foxes in southwestern Wisconsin indicates that the population is declining due to the combination of high harvest rates and low productivity. Because Petersen et al. (1977) concluded that about 50% of the fall population was being harvested annually, it is conceivable that the gray fox population could be eliminated from Wisconsin unless effective regulations are initiated (see above) and future research is conducted. Therefore, gray foxes should be live-trapped (Berchielli and Tullar 1980, Tullar and Berchielli 1980), sexed, aged (Root 1981), ear-tagged, radio-collared (Follman and Buitt 1978), and released, with emphasis on investigating spring and summer sex ratios of litters and adults, annual survivorship and mortality patterns of tagged animals, and dispersal patterns and habitat use. All foxes collected after tagging should be aged (Root 1981) to verify cementum annuli procedures (Nicholson and Hill 1980, Root 1981). The state population should be monitored through a tyvac tagging program and the analysis of the age structrure and reproductive performance of a representative sample of the fall gray fox harvest, and future management decisions based on the analysis of this data.

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Accepted ____________________.

Table 1. Age-related litter size[a] and percentage of barren vixens for 96 gray foxes from southwestern Wisconsin, 1978-80.

Age (years)	Sample N	Percent barren	Mean litter size	Range
1.5	54	18.5	3.41	1-9
2.5	25	4.0	3.38	1-9
3.5	9	0.0	4.11	2-8
4.5+	8	0.0	3.63	2-5
Total	96	11.5	3.49	1-9
2.5+	42	2.4	3.59	1-9

[a] From placental scar counts.

Table 2. Mean litter sizes of gray foxes from different regions of the United States.

Reference	Location	Sample N	Mean litter size[a]
Lord 1961	Florida	Unknown	4.7(s)
Lord 1961	Florida	6	3.3(s)
Wood 1958	S. Georgia & N. Florida	141	4.6(s,e)
Sullivan 1956	Alabama	26	3.8(s,e)
Layne 1958	S. Illinois	66	4.4(cl)
Gier 1947	Ohio	Unknown	5.2(cl)
Sheldon 1949	New York	35	3.7(s,e)
Layne and McKeon 1956	New York	42	4.5(s,e)
Richards and Hine 1953	S. Wisconsin	44	3.9(s)
Current study	SW. Wisconsin	85	3.5(s)

[a] s = placental scars, e = embryos or fetuses, cl = corpora lutea.

Table 3. Number of gray foxes examined and percentage with mature sperm present in the cauda epididymis, by month in southwestern Wisconsin, 1978-80.

Month	Juvenile		Adult	
	Sample N	Percent with sperm	Sample N	Percent with sperm
November	34	15.6	14	78.6
December	17	64.7	12	83.3
January	12	100.0	8	100.0

Table 4. Age structure of gray foxes trapped and pelted by trappers and those sold to furbuyers unpelted in southwestern Wisconsin, 1978-80.

Age (years)	Foxes trapped and pelted		Foxes trapped and sold unpelted		Combined	
	N	%	N	%	N	%
0.5	46	58.8	115	69.8	161	66.3
1.5	18	23.1	26	15.7	44	18.1
2.5	8	10.3	14	8.5	22	9.1
3.5	1	1.3	3	1.8	4	1.5
4.5	2	2.6	4	2.4	6	2.6
5.5	2	2.6	2	1.2	4	1.5
6.5	1	1.3	1	0.6	2	0.9
Total	78	100.0	165	100.0	243	100.0

Table 5. Composite life table for gray foxes from southwestern Wisconsin, November - January 1978-80.

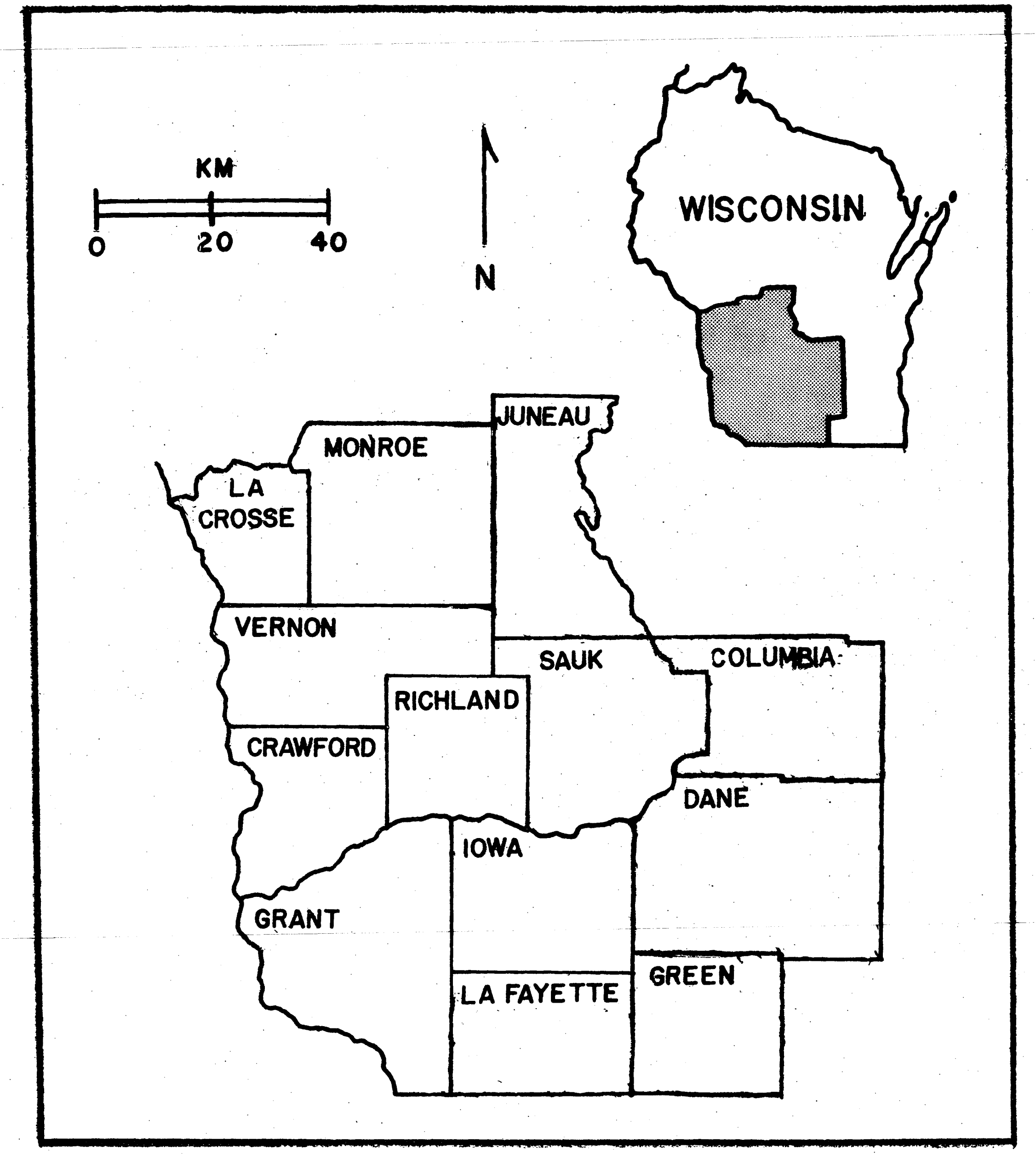
Age (years)	No. alive	No. alive (Per 1000)	No. dead	Mortality rate	Mean expectation of further life (years)
x	l_x	l_x	d_x	q_x	e_x
0.5	420	1000	719	0.719	1.014
1.5	118	281	143	0.509	1.329
2.5	58	138	90	0.652	1.188
3.5	20	48	27	0.562	1.479
4.5	9	21	2	0.095	1.738
5.5	8	19	12	0.632	0.869
6.5	3	7	7	1.000	0.500
Total	636	1514	1000	0.660	1.109
Adult	216	514	281	0.546	1.294

Table 6. Calculation of net reproductive rate (R_o) for gray foxes from southwestern Wisconsin, 1978-80.

Age (years) x	Sample l_x	Per 1000 l_x	Natality m_x[a]	Reproductive rate $l_x m_x$
0.5	217	1.00	0.00	0.00
1.5	59	0.27	1.39	0.38
2.5	26	0.12	1.62	0.19
3.5	10	0.05	2.06	0.10
4.5+	11	0.05	1.82	0.09
				0.76 = R_o

[a] A sex ratio at birth of 50:50 was assumed.

Fig. 1. Gray fox study area in southwestern Wisconsin.



KM
0
20
40
N
WISCONSIN
JUNEAU
MONROE
LA CROSSE
VERNON
SAUK
COLUMBIA
RICHLAND
CRAWFORD
DANE
IOWA
GRANT
GREEN
LA FAYETTE

Fig. 2. Placental scar counts of 85 gray foxes from southwestern Wisconsin, 1978-80.

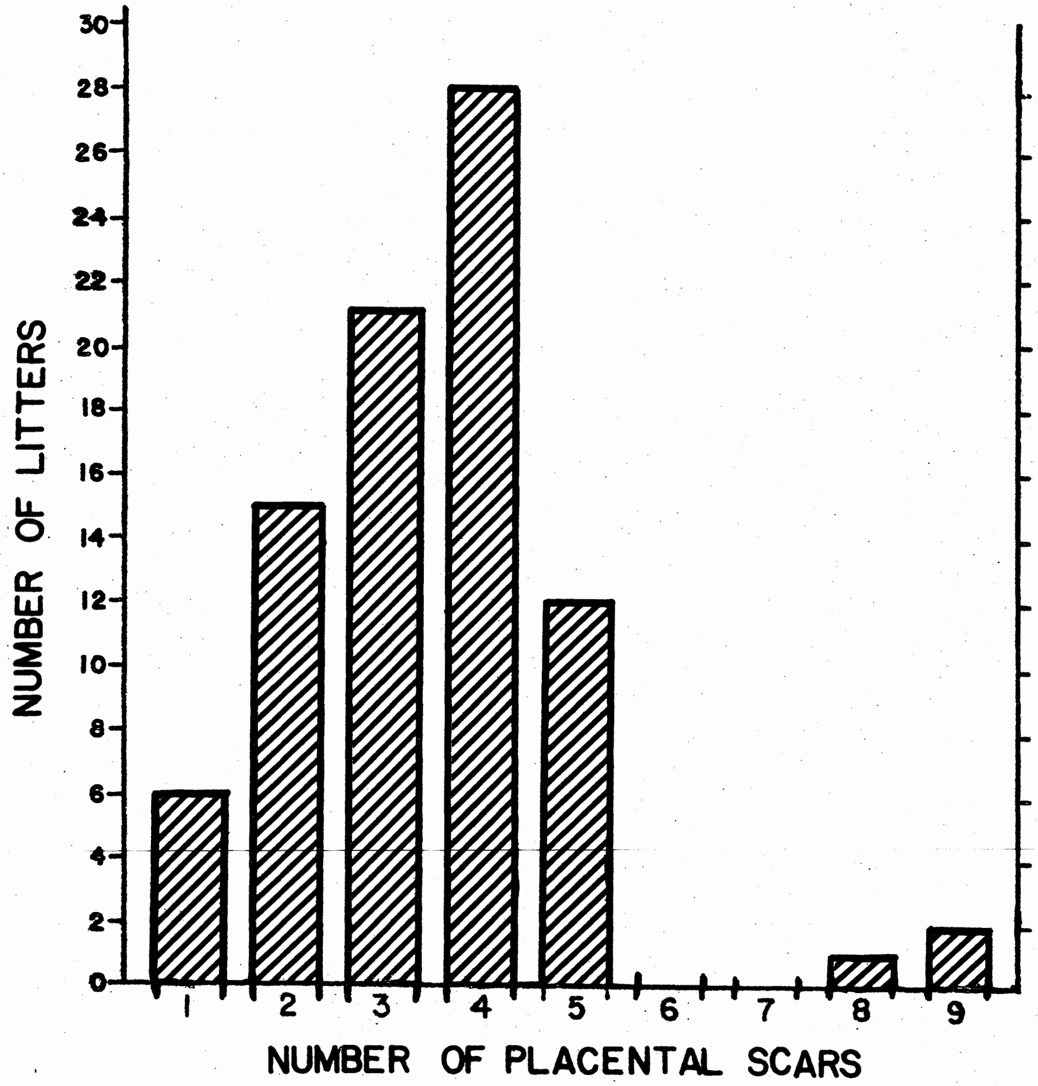

NUMBER OF LITTERS
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
NUMBER OF PLACENTAL SCARS

Fig. 3. Average testes weight of 63 juvenile (dashed line) and 35 adult (solid line) gray foxes from southwestern Wisconsin, 1978-80. Breeding coefficients were calculated for each animal to reduce the bias caused by variations in body size of males.

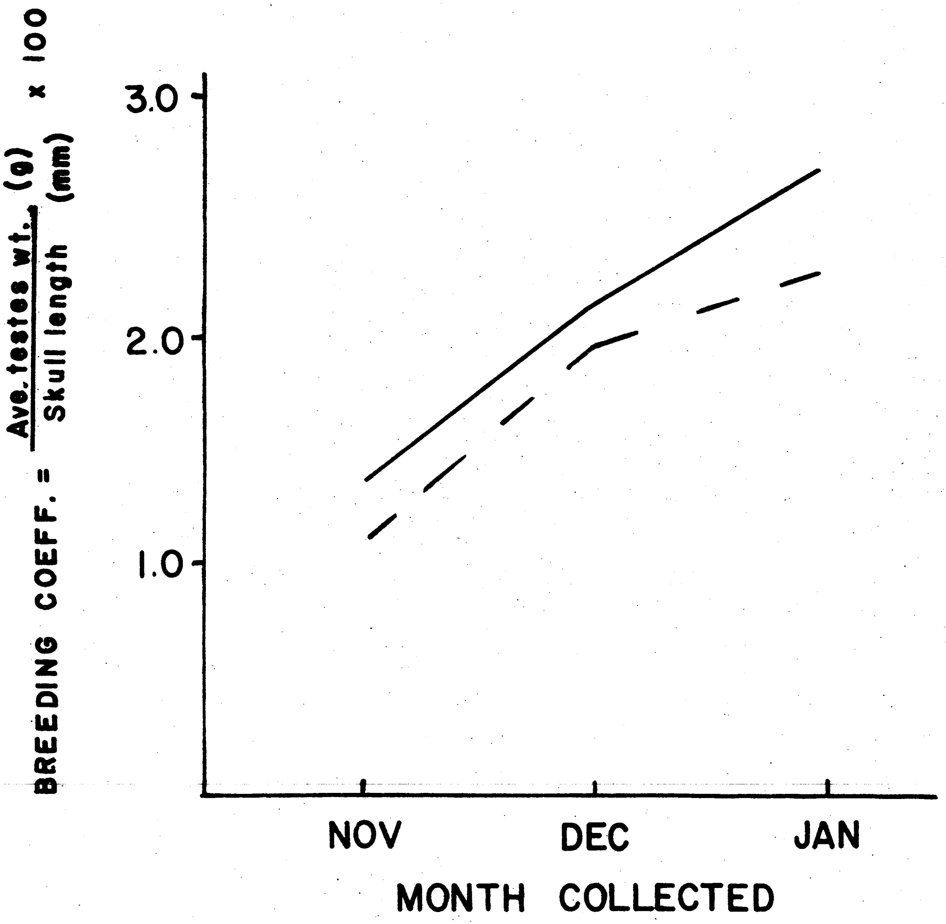
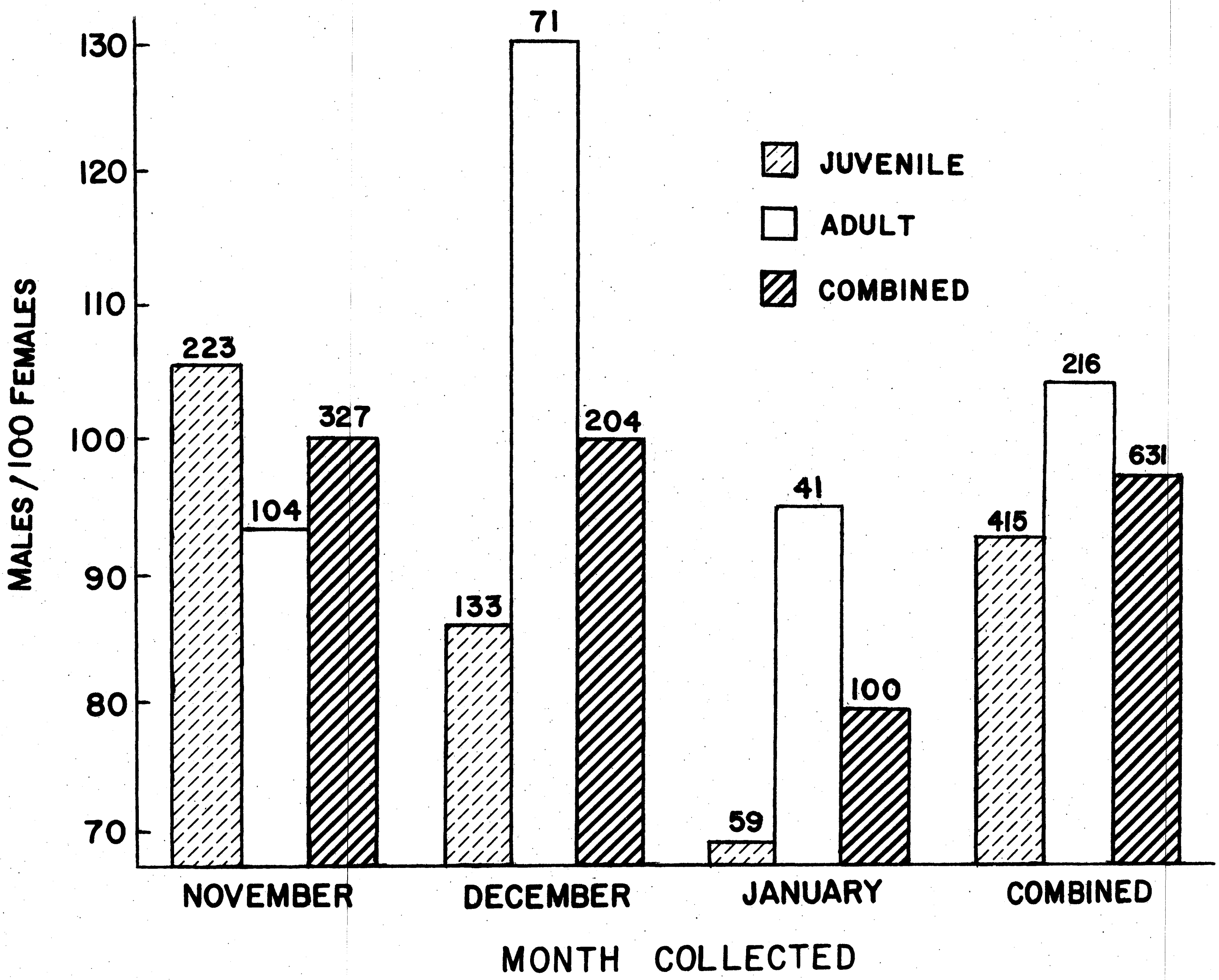

BREEDING COEFF. = Ave. testes wt. (g) / Skull length (mm) x 100
3.0
2.0
1.0
NOV
DEC
JAN
MONTH COLLECTED

Fig. 4. Monthly variation in sample sex ratio in relation to age, for 631 gray foxes from southwestern Wisconsin, 1978-80. Numbers above bars indicate sample sizes for each age-class.



130
120
110
100
90
80
70
MALES / 100 FEMALES
JUVENILE
ADULT
COMBINED
223
104
327
71
133
204
59
41
100
415
216
631
NOVEMBER
DECEMBER
JANUARY
COMBINED
MONTH COLLECTED

Fig. 5. Monthly variation in sample sex ratio in relation to cause of death, for 500 gray foxes from southwestern Wisconsin, 1978-80. Numbers above bars indicate sample sizes for each category.

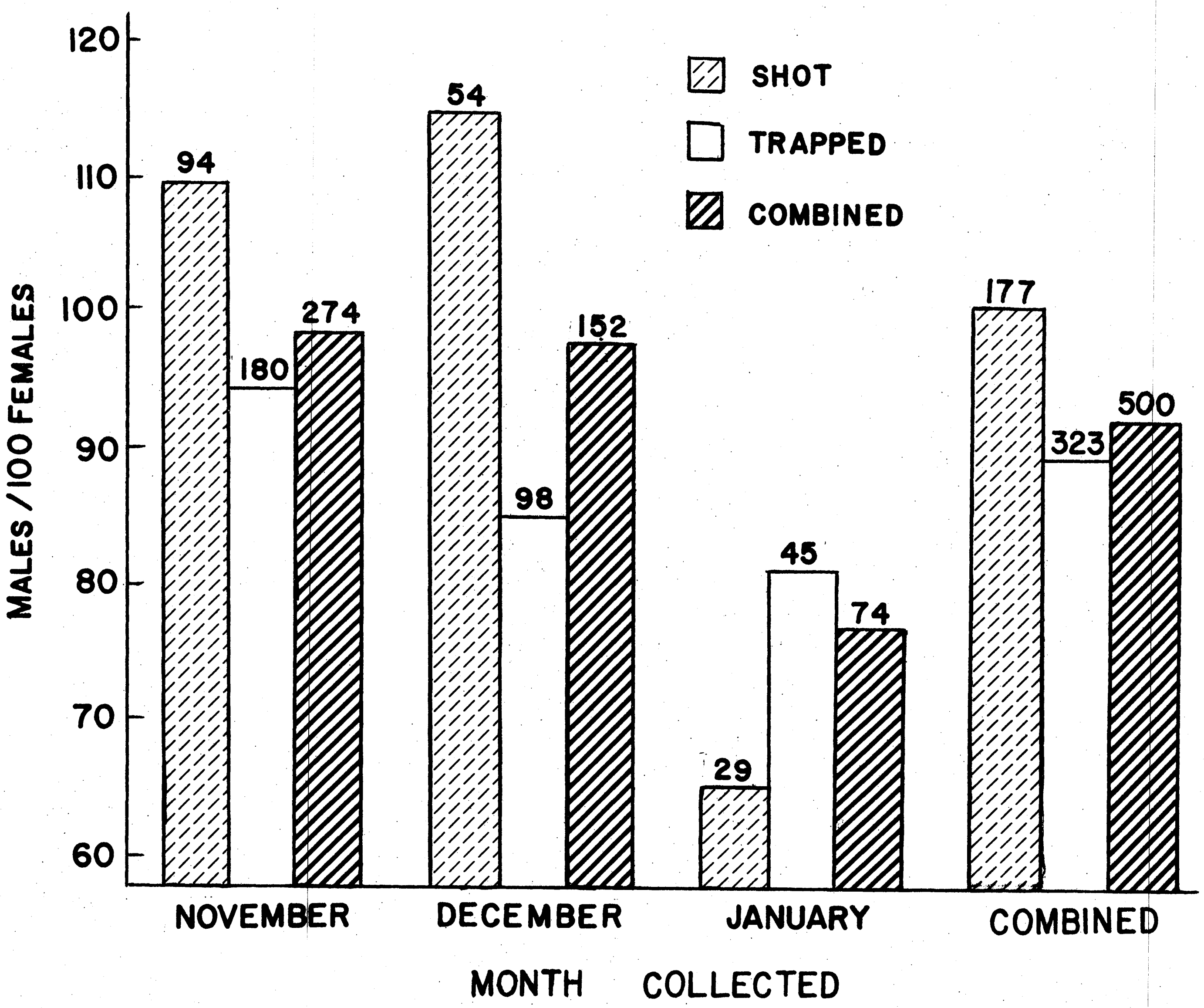

MALES / 100 FEMALES
120
110
100
90
80
70
60
SHOT
TRAPPED
COMBINED
94
180
274
54
98
152
29
45
74
177
323
500
NOVEMBER
DECEMBER
JANUARY
COMBINED
MONTH COLLECTED

Fig. 6. Causes of death of 547 gray foxes from southwestern Wisconsin, 26 October - 31 January 1978-80. Numbers above bars indicate sample sizes in each category.

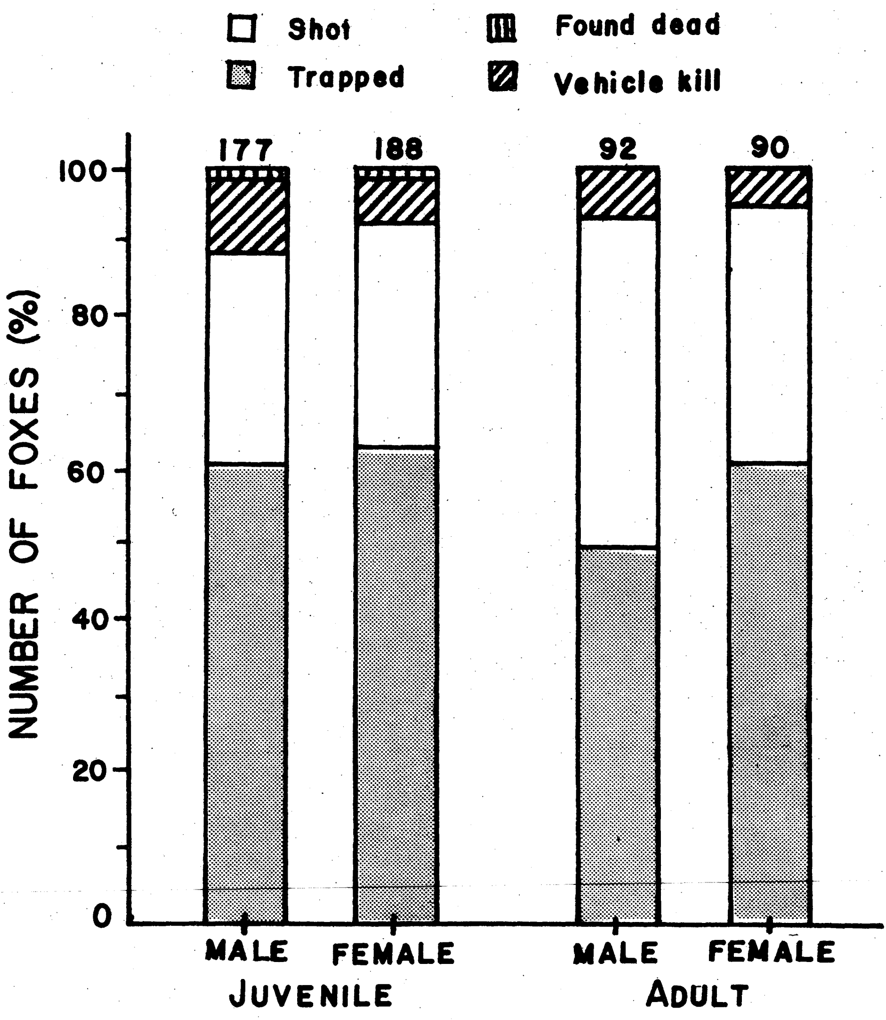

Shot
Found dead
Trapped
Vehicle kill
NUMBER OF FOXES (%)
0
20
40
60
80
100
177
188
92
90
MALE
FEMALE
JUVENILE
MALE
FEMALE
ADULT

Fig. 7. Number of gray foxes harvested each month (%) in southwestern Wisconsin, 1978-80.

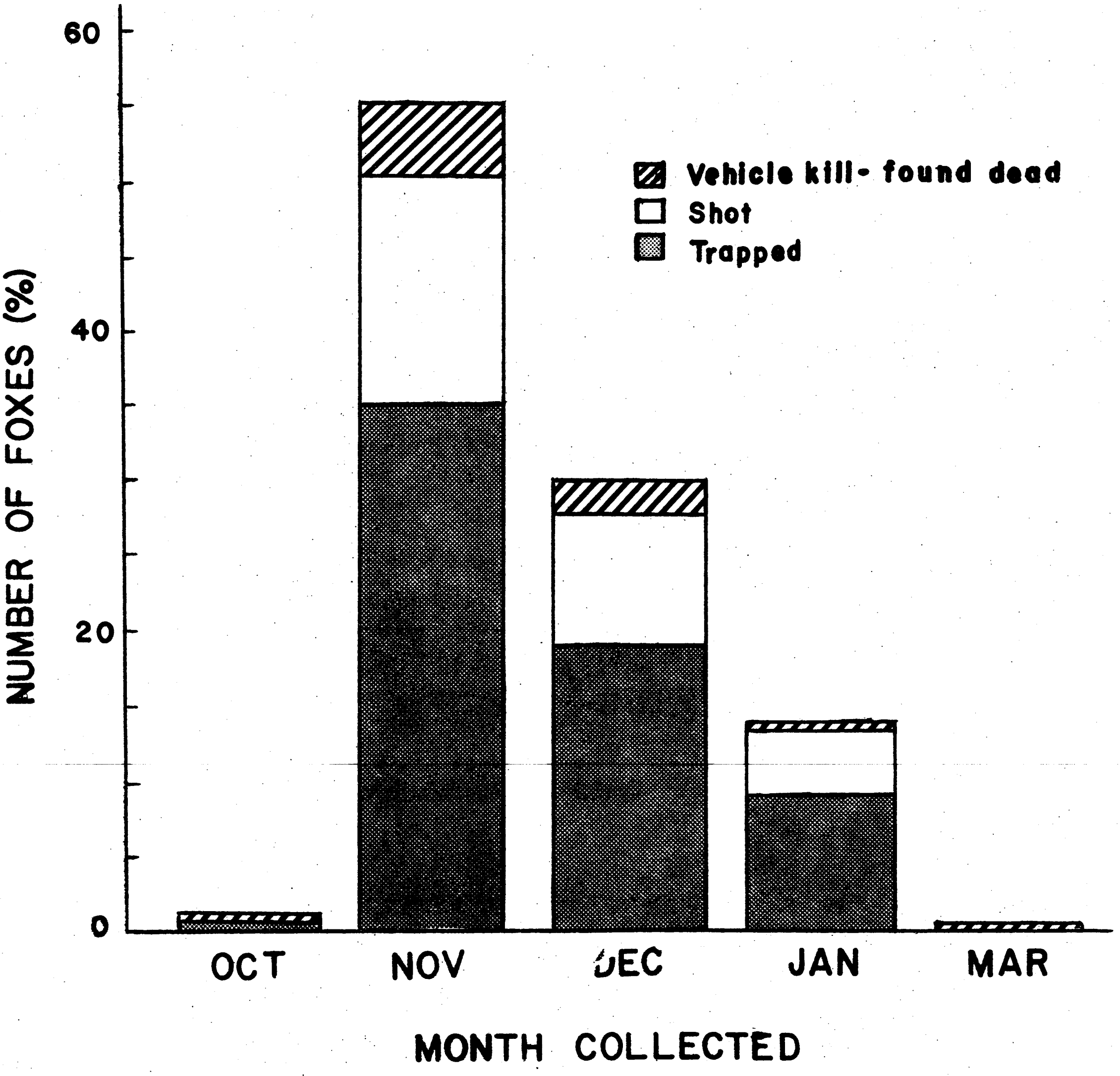

60
40
20
0
NUMBER OF FOXES (%)
Vehicle kill- found dead
Shot
Trapped
OCT
NOV
DEC
JAN
MAR
MONTH COLLECTED

Fig. 8. Number of male and female gray foxes harvested each month (%) in southwestern Wisconsin, 1978-80. Numbers above bars indicate sample sizes that month.

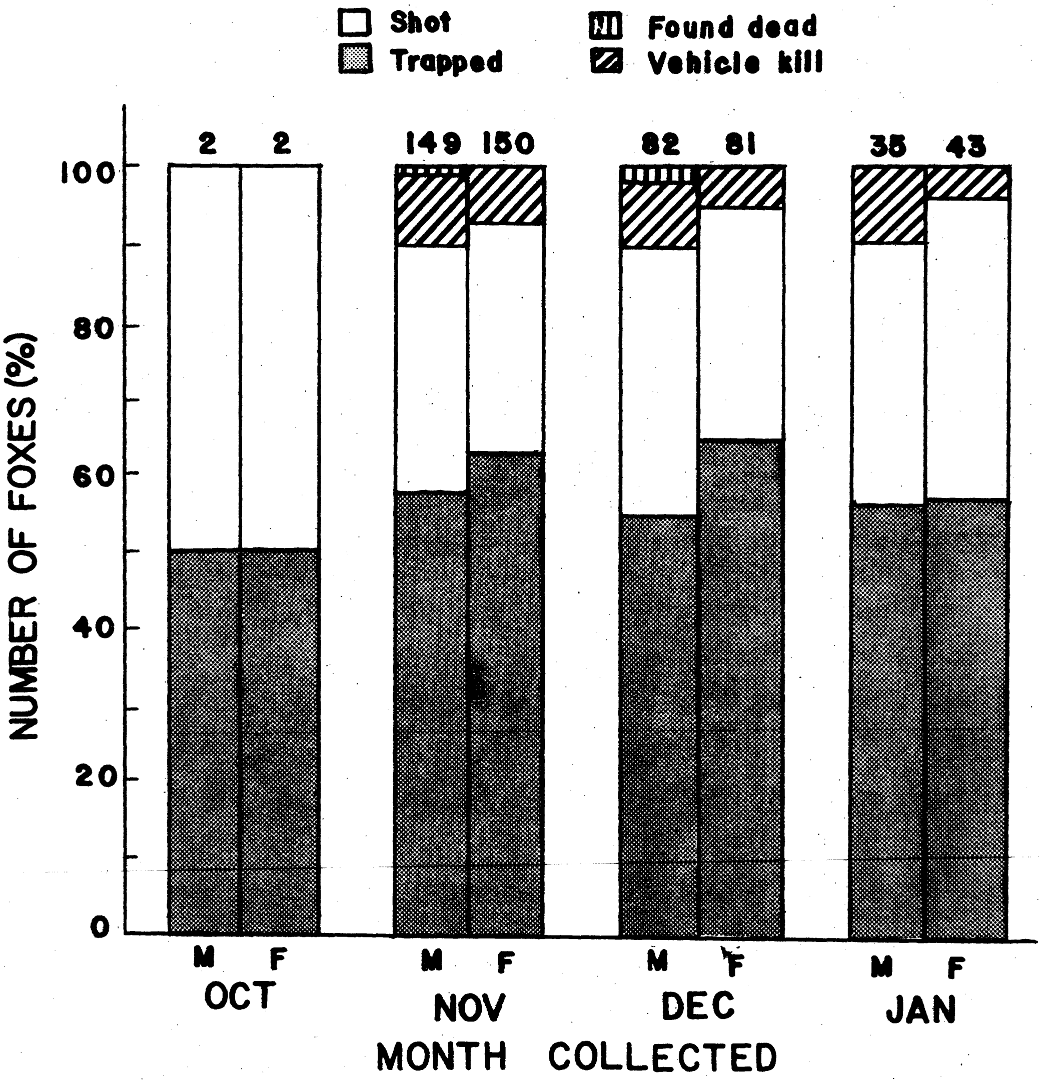

Shot
Trapped
Found dead
Vehicle kill
NUMBER OF FOXES (%)
0
20
40
60
80
100
2
2
149
150
82
81
35
43
M
F
OCT
M
F
NOV
M
F
DEC
M
F
JAN
MONTH COLLECTED

Fig. 9. Age distribution (%) of gray foxes from southwestern Wisconsin, 26 October - 31 January 1978-80. Numbers of each age group are listed along bars.

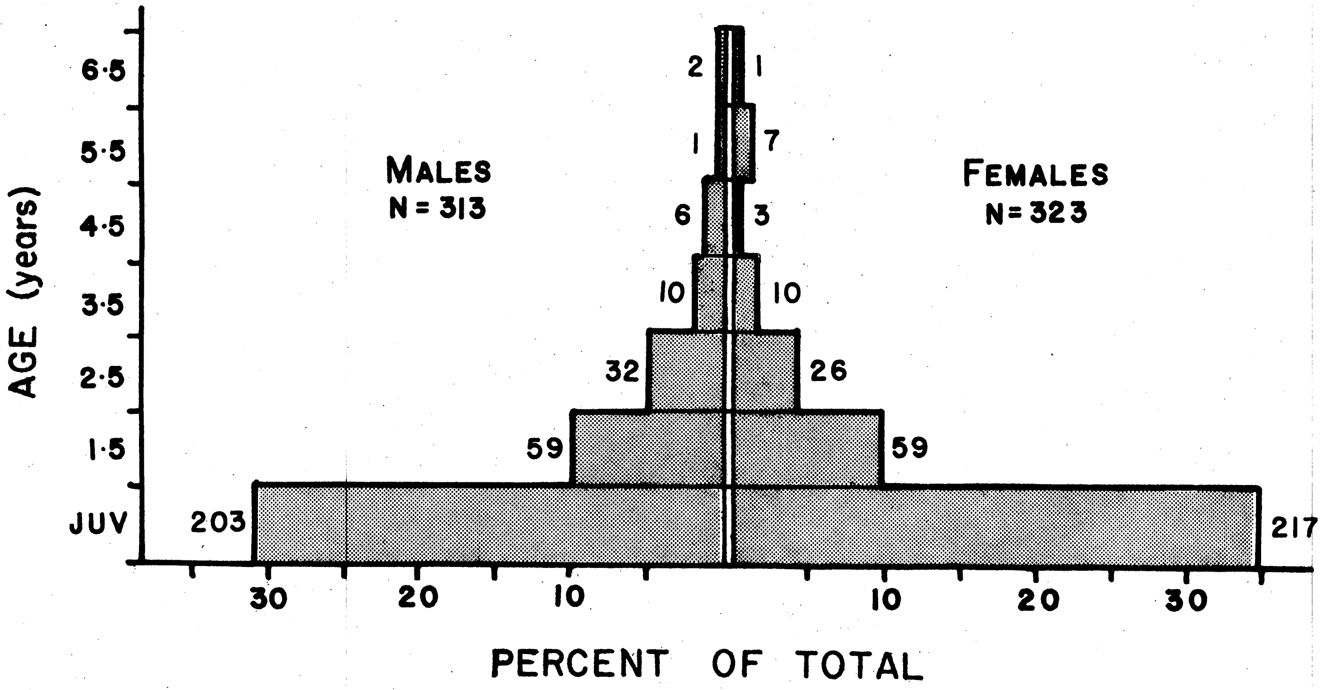
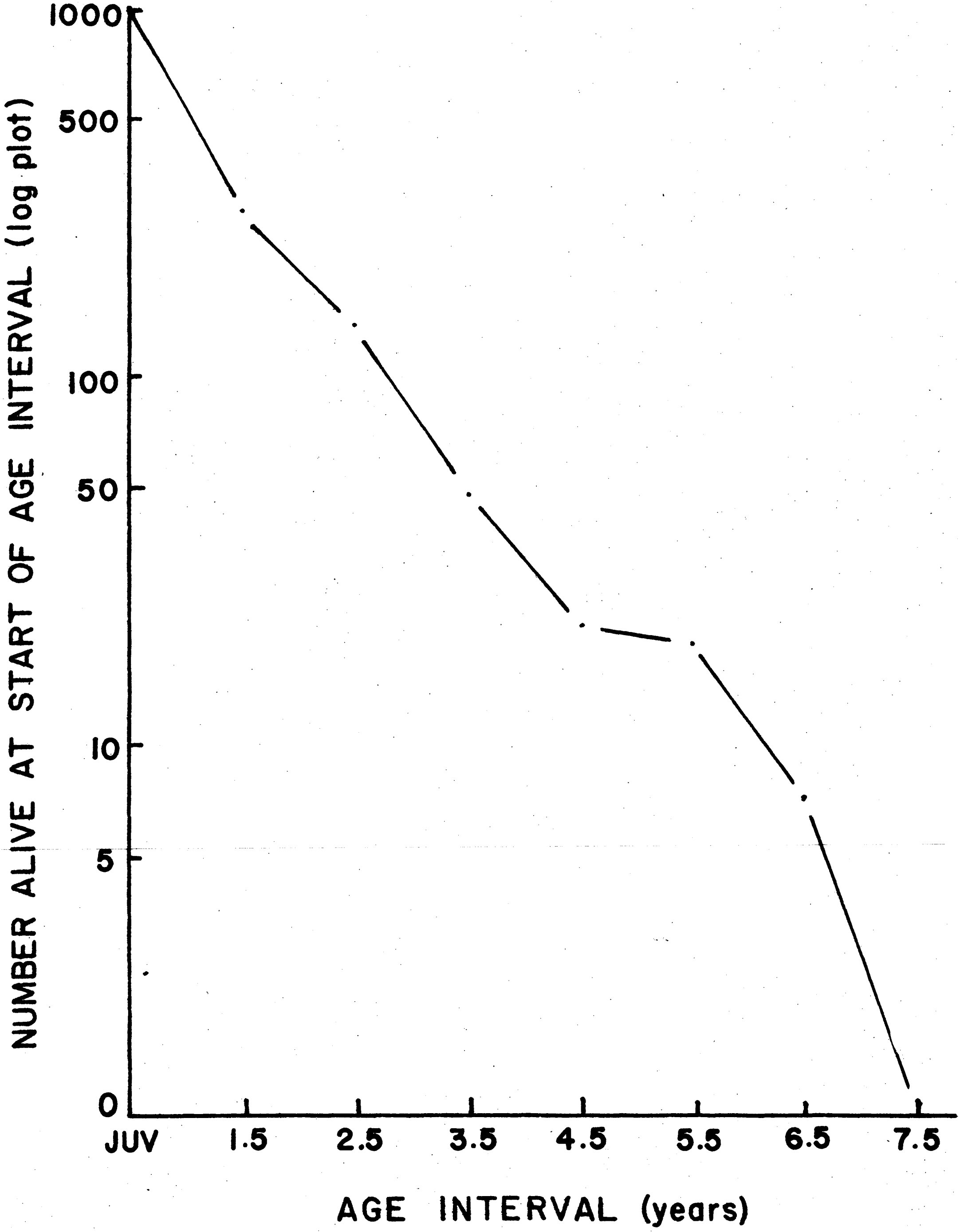

MALES
N = 313
FEMALES
N = 323
AGE (years)
6·5
5·5
4·5
3·5
2·5
1·5
JUV
2
1
1
7
6
3
10
10
32
26
59
59
203
217
30
20
10
10
20
30
PERCENT OF TOTAL

Fig. 10. Survivorship curve of 631 gray foxes from southwestern Wisconsin, 1978-80.


1000
500
100
50
10
5
0
NUMBER ALIVE AT START OF AGE INTERVAL (log plot)
JUV
1.5
2.5
3.5
4.5
5.5
6.5
7.5
AGE INTERVAL (years)

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PRODUCTIVITY AND MORTALITY OF RACCOONS IN SOUTHWESTERN WISCONSIN

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Abstract: Age-specific, sex-specific, and mean annual mortality and reproductive rates were gathered from 1,361 raccoon (*Procyon lotor*) carcasses collected in southwestern Wisconsin from 13 October through 31 January 1978-80. Litters averaged 3.71 young for 32% of 72 yearlings and 3.72 for 91% of 142 older adults; however, the mean number of pups per yearling (1.17) was significantly less ($P < 0.01$) than per older adult (3.38) due to the higher incidence of barren yearlings (68%) than older adults (9%). Age-specific litter size remained fairly constant through at least the 10th year. About 10% of 100 juveniles harvested in October 1979 were born between mid-May and mid-July. Starvation and lack of subcutaneous fat reserves on 19 other juveniles suggest that animals conceived later than the normal February through March mating period may not survive a long winter in Wisconsin. Low testes weight, lack of non-motile sperm in smears, and non-extrusible penes indicate that juvenile males in southwestern Wisconsin are not capable of siring offspring. The sex ratio of juveniles (116M:100F) significantly ($P < 0.05$) favored males; adults were nearly equally divided by sex (96M:100F, $P > 0.05$). Over 98% of known mortality was attributed to hunting (43%) and trapping (55%). The harvest consisted of 65% juveniles, 13% yearlings, and 22% older adults. Maximum longevity approached

10 years although few raccoons (5%) survive more than 5.5 years of life. The net reproductive value (0.83) indicated a declining raccoon population during this study. Management recommendations include shortening the current raccoon season (about 15 October - 31 January) to coincide with the present red fox (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*) hunting and trapping seasons (about 1 November - 31 January).

J. WILDL. MANAGE.

Key words: age structure, management recommendations, mortality, *Procyon lotor*, raccoons, reproduction, sex ratios, southwestern Wisconsin.

The Wisconsin Department of Natural Resources initiated a raccoon stocking program for Wisconsin in 1932 to increase the number of raccoons available for hunting opportunities while improving pelt values through the introduction of black and cross raccoons. Terminated about 30 years later, this program did not contribute to the annual raccoon harvest, supplement existing populations, or establish new populations on new ranges (Woehler 1957); however, since 1948 the raccoon population has steadily increased to the point where they have become so abundant in some areas that they cause damage to summer homes, agricultural crops, waterfowl nests (Woehler 1957), and young muskrat (Ondatra zibethicus) populations (Dorney 1954).

Concurrently, interest in hunting and trapping raccoons in Wisconsin has increased dramatically due to increasing pelt values. Estimated fur purchases ranged from 53,000 Wisconsin raccoon pelts in 1967 to an average of over 94,600 pelts during the following 10 years (Fig. 1). Of 39 states reporting, Wisconsin ranked 4th in the harvest of raccoons in 1976 (Inter. Assoc. Game and Fish Conserv. Comm. 1977, unpubl. report). The total estimated value of Wisconsin raccoon pelts during the 1975-76 trapping season was about $3.15 million. Muskrats were ranked 2nd at $2.23 million (Wisconsin Dep. Nat. Resour. 1976a).

There is a need to investigate the productivity and mortality rates of the Wisconsin raccoon population under the current intensive hunting and trapping pressure. The objectives of this study were to determine age-specific, sex-specific, and mean annual mortality and reproductive rates of raccoons in southwestern Wisconsin.

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STUDY AREA

Raccoon carcasses were collected within a 13-county region of southwestern Wisconsin (Fig. 2). This area is characterized by open hills with broad ridges in southern regions to deeply incised valleys with narrow ridges in the north (Hole 1977). Croplands are found on ridge tops and valley floors; intervening slopes are wooded. About 30% of the land surface is cropped, and 40% forested (Petersen et al. 1977) with predominately white oak (*Quercus alba*), red oak (*Q. rubra*), black oak (*Q. velutina*), white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), and maple-basswood (*Acer* spp. - *Tilia americana*) associations (Curtis 1959).

METHODS

Reproductive organs and upper mandibles of 1,361 raccoons were collected from 13 October - 31 January 1978-80. About 75% of the raccoons were collected from cooperating furbuyers once each week; the remainder was saved by trappers and hunters who were instructed how to collect and store relevant parts. Most raccoons (98%) were trapped or shot, but starved animals (Mech et al. 1968) and traffic victims were also reported or identified.

Carcasses were frozen as soon as possible after collection, and sex, date of capture, cause of death, and county of kill were recorded.

Juvenile raccoons were distinguished from adults by the presence of canine root apical foramina (Grau et al. 1970), and aged to the nearest half month by tooth replacement patterns (Montgomery 1964) when possible. All remaining specimens were aged by counting cementum annuli of an upper 1st premolar (Root 1981*a*). Past studies have determined raccoon ages from counts of annuli from upper incisors (Grau et al. 1970) or 4th premolars (Johnson 1970); however, numerous accessory lines (Rice 1980) were present in those teeth which were not apparent in upper 1st premolars. Although Stone et al. (1975) used giemsa to stain annuli of raccoons from New York, bands of southwestern Wisconsin raccoons were indistinguishable unless stained with hematoxylin and eosin. Similar results were noted with sectioned teeth of Wisconsin gray foxes, red foxes, coyotes (*Canis latrans*), and black bears (*Ursus americanus*).

The penis was examined from each male raccoon to determine if it could be extruded through the prepubital orifice (Sanderson 1950, 1961). Testes with attached epididymides were weighed to the nearest 0.1 g, and smears from the cauda examined for presence of non-motile spermatozoa. To reduce the bias caused by body size differences, the average weight of each animal's testes (g) was divided by the greatest skull length (mm) and multiplied by 100 (Payne et al. 1966, Gipson et al. 1975).

Litter sizes were determined from placental scar counts from the most recent breeding season (Johnson 1970). Females with turgid uteri were not examined because estrus tends to obscure the scars (Johnson 1970, Sanderson and Nalbandov 1973).

All raccoons aged at ≥1.5 years were designated as adults; raccoons <1.5 years as juveniles; and those aged at 1.5 years old as yearlings. Barren adults refer to female raccoons that produced no offspring, either through failure to mate, failure of eggs to be fertilized, or loss of embryos prior to implantation or shortly thereafter, and showing no evidence of pregnancy or placental scars in the uterine horns.

RESULTS

Reproduction

Males

Average testes weights of adults were significantly greater ($P < 0.001$) than juveniles for each month of collection and all months combined. Testes of all 67 juveniles weighed ≤3.4 g and showed no apparent weight growth from October through January. Testes of yearlings reached the adult weight range (≥7.3 g) by October or earlier. Only 4% of 67 juveniles had mature sperm in the cauda epididymis; all 19 yearlings and 88% of 42 older adults were reproductively active. By December, all 14 adults and no juveniles possessed mature sperm (Fig. 3).

The baculum could be extruded through the prepubital orifice of all 37 adults, but none of 40 juveniles examined.

Females

About 71% of 214 adult females whelped young during the year in which they were examined (Table 1). Of the 62 females showing no discernible evidence of placental scars (considered barren), 79% (N=49) were yearlings; the remainder were older adults. About 68% of 72 yearlings and only 9% of 142 older females were barren.

The mean litter size of 152 females was 3.71 young. Scar counts ranged from 1 to 7; mode litter size was 4 (Fig. 4). Although the mean litter size of yearlings (3.65) and older adults (3.72) did not differ ($P > 0.05$), the mean number of young per yearling (1.17) was significantly less ($t = 9.36$, $P < 0.01$, N=152) than per older adult (3.38) due to the higher incidence of barren yearlings than older adults.

Age-specific litter size remained fairly constant from 3.45 to 4.11 young through 6.5 years of life. Beyond that, litter sizes increased slightly but sample sizes were too small to determine statistically significant differences.

Late Litters

About 10% of 100 juvenile raccoons collected in October 1979 were conceived later than the normal mating season of late January through mid-March in Wisconsin (Jackson 1961). Ages assigned to these animals and 7 juveniles collected in November 1979 indicated that late litters were born between 15 July and mid-September and were conceived from 15 May through mid-July (Table 2). These raccoons, and 19 additional juveniles, showed a total lack of subcutaneous fat reserves.

Sex Ratios

The overall sex ratio of 1,339 raccoons collected during this study was 109M:100F (52% males). The sex ratio of 856 juvenile raccoons (116M:100F) favored males ($X^2=4.83$, $P < 0.05$, 1 df); 483 adults were nearly equally divided by sex (96M:100F, $P > 0.05$, Table 3). Although more juvenile than adult males apparently were harvested each month and for all months combined (Fig. 5), the differences were not significant ($P > 0.05$).

Age Structure

Of 1,361 raccoons that were classified into 1-year age groups, 875 (65%) were collected as juveniles, 13% as yearlings, and 22% as older adults (Fig. 6). Maximum longevity of males and females approached 8 and 10 years, respectively, although few raccoons (5%) survive more than 5.5 years. Mean expectation of further life for the combined sample was 1.36 years; life expectancy was 1.05 years for juveniles and 1.90 years for adults (Table 4).

No differences were apparent when age ratios were compared to method of capture ($P > 0.05$), but 86% of 22 raccoons killed in vehicle collisions were under 1 year of age (Table 5). The juvenile:adult ratio remained relatively constant through December but indicated that there may be a greater percentage of adults harvested in January (Fig. 7).

Mortality

The age distribution of the sample (Fig. 6) was assumed to represent that of the living population, and was treated as an "l_x" series (Caughley 1966, Seber 1973). Life table analysis indicated that overall mortality of raccoons was 64%. Mortality of juveniles (80%) was less ($X^2=8.41$, $P < 0.005$, 1 df) than for adults (37%, Table 4), but this may be biased because juveniles are harvested greater than their frequency of occurrence in the population (Johnson 1970). Mortality rates of yearlings through 6.5 year olds remained fairly constant at from 24% to 45%. Beyond that, mortality increased but sample sizes were too small to determine statistically significant differences. The survivorship curve (Fig. 8) resembles the type II curve for species assumed to have relatively constant survival throughout life (Boughey 1973).

Overall, 98% of known mortality resulted from hunting (43%) and trapping (55%). Vehicle kills accounted for the remaining 2%. Equal numbers of both sexes were harvested by hunting and trapping (Fig. 9). Although individuals reported diseased and dying raccoons, the exact magnitude of disease-related mortality is unknown but suspected of being important.

Population Stability

The net reproductive rate, R_o (Odum 1971) was calculated from the female data (Table 1 and Fig. 6) to indicate the stability of the population during this study. If an equal sex ratio at birth is assumed, and the mean number of young per female (Table 1) accurately represents the productivity of female raccoons in southwestern Wisconsin, the replacement rate for both years combined was 0.83 (Table 6). Since an R_o value of 1.0 means the population is replacing itself every generation, a value of 0.83 indicates a slowly declining raccoon population during this study.

DISCUSSION AND CONCLUSIONS

Reproduction

Only 32% of the yearling female raccoons collected in southwestern Wisconsin during this study bore evidence of having produced offspring. Sanderson and Nalbandov (1973) concluded that yearling females from Illinois either conceive at the same time as adults during their 1st estrus period or they do not breed until the next breeding season. Johnson (1970), Cowan (1973), and Fritzell (1978) indicated that yearlings conceive somewhat later in the year than do adults. If a female failed to become pregnant during her 1st estrus or her litter died immediately after birth, she could ovulate again from 1 to 6 months later (Whitney and Underwood 1952, Schneider et al. 1971, Sanderson and Nalbandov 1973). Two groups of females, late-maturing juveniles and reovulating adults, may be reproductively active throughout most of the spring and summer (Fritzell 1978). In southwestern Wisconsin, about 10% of all juveniles harvested in October 1979 resulted from late litters conceived from mid-May through mid-July, indicating that some females are ovulating in a 3-month period during the summer.

There is a general tendency for raccoon litter sizes to increase in the more northern latitudes (Johnson 1970). Mean litter sizes of 3.71 in southwestern Wisconsin (latitude 44°N) agreed closely with 4.1 young (Cowan 1973) for Manitoba (latitude 49°N to 52°N) and 4.5 young (Fritzell 1978) for North Dakota (latitude 48°N). Severe winter temperatures and the length of winter appear to be important mortality factor (Mech et al. 1968). Genetic variablity in reproductive capacity (Bissonnette and Csech 1937, Lord 1960), qualitative nutrition through soil fertility (Stevens 1962, Williams and Caskey 1965), and length of the reproductive season (Spencer and Steinhoff 1968) seem to affect litter sizes of other mammals, but geographic variations in litter sizes of raccoons cannot be explained with the information presently available (Johnson 1970). Several combinations of many factors contribute to latitudinal differences in litter size.

The mean number of young per yearling in southwestern Wisconsin (1.17) was significantly less ($\underline{P} < 0.01$) than per older adult (3.38) due to the high incidence of yearling females that did not produce offspring. In Manitoba, Cowan (1973) noted that although the mean litter size of comparably aged adults was high (4.11), yearlings produced only 0.8 young per litter. At this rate the contribution of a yearling female to the total recruitment of young would be low, but the greater number of available yearlings than older adults compensates for the smaller mean litter size.

Testes of males from southwestern Wisconsin do not reach adult size or produce sperm until at least the end of the 1st year of life, as suggested for North Dakota (Fritzell 1978) and Manitoba (Cowan 1973). Juvenile males therefore probably contribute very little to the annual recruitment in southwestern Wisconsin. However, most juvenile males in Illinois are thought to sire most litters produced from second ovulations (Sanderson and Nalbandov 1973). Similarly, Johnson (1970) found that most males have adult-sized testes during the 1st breeding season in Alabama. The relatively short frost-free season and the long cold winters in the northern portion of the raccoon range may retard the attainment of physical maturity necessary for breeding during the 1st year of life (Fritzell 1978). The penis of all 40 juvenile males from southwestern Wisconsin could not be extruded through the prepubital orifice, thus they were also physically incapable of mating.

If adverse weather conditions prevent early spring conceptions, litters from 2nd ovulations are born in the fall (Stuewer 1943a, Berard 1952, Whitney and Underwood 1952, Lehman 1968, Schneider et al. 1971). Sanderson and Nalbandov (1973) noted that about 16% of the juvenile raccoons purchased by furbuyers in the fall following the abnormally severe spring weather of 1960 in Illinois were born from August through October. In Manitoba, 14% of births were as late as the 1st week of September (Cowan 1973). About 10% of the raccoons collected in October 1979 in southwestern Wisconsin were juveniles conceived from 2nd ovulations from May through July. Although deep snows during the normal February raccoon mating season may have impeded the successful movement, location, and mating of receptive raccoons during the winter of 1978-79, the exact causes remain unknown. Malnutrition and disease in winter adversely affected the success for first-estrus matings in Manitoba (Cowan 1973), and both were reported in southwestern Wisconsin.

If we consider the energy demands during pregnancy, the 8 to 10 week nursing period, and the lengthy female-young relationship

(Schneider et al. 1971, Fritzell 1977), late litters would be especially maladaptive in the severe winter climates in Wisconsin. Litters produced in the milder environments of the southern United States may be benefited by second ovulation and fertile juvenile males, but survival of juveniles whelped from late breeding females would add little to the total annual recruitment in Wisconsin. My observations of 4 starved juveniles and 19 others lacking subcutaneous fat reserves suggests that many young raccoons may not survive a long and severe winter in Wisconsin. The body weight of juveniles in Manitoba decreased about 30% over winter, and winter mortality was possibly as high as 60% for this age class (Cowan 1973). Delayed maturity and larger litters in northern latitudes apparently compensates for recruitment from late breeding yearlings in southern ranges.

Sex Ratios

An extensive literature review revealed no apparent relationship between sex ratios and method of capture or geographic region of kill (Table 7). In southwestern Wisconsin, the ratio of males to females did not differ from an assumed 50:50 ratio. However, the ratio of juveniles favored males because males apparently are more active than females, and range over larger areas (Fritzell 1977), thus making them more susceptible to capture. Greater susceptibility of males is not related to fall dispersal as commonly occurs with other species (e.g. Storm et al. 1976). In the northern portion of their range, dissolution of raccoon sibling bonds occurs during the spring following the 1st winter of life (Mech and Turkowski 1966, Schneider et al. 1971, Fritzell 1977). The equal sex ratio of adults in southwestern Wisconsin may result from fewer males being available for capture.

Mortality

Hunting and trapping accounted for 98% of known human-related mortality of raccoons in southwestern Wisconsin. Only 2% of the raccoons were reported killed on roads, indicating that mortality due to vehicle collisions was not an important factor.

The exact magnitude of disease-related mortality in southwestern Wisconsin was unknown, but reports from concerned trappers and hunters suggest that it may be important. Distemper inhibited the population growth of raccoons in Indiana (Lehman 1977) through the loss of yearlings or pregnant females.

Lack of subcutaneous fat reserves on 19 juveniles and 4 starved animals indicate that malnutrition affects raccoon survival in southwestern Wisconsin. Starvation was an important mortality factor in Minnesota (Mech et al. 1968); the lack of food was a major contributing factor to the 60% juvenile winter mortality rate noted in Manitoba (Cowan 1973). Nutritional deficiencies are probably most important in weakening the animal and reducing resistance to parasitism and disease (Johnson 1970).

In southwestern Wisconsin, highest mortality (80%) occurred during the 1st year of life, and remained fairly constant from 24% to 45% thereafter.

Age Structure

Raccoon populations in northern states have proportionately more juveniles and a more rapid turnover rate than those in southern areas (Johnson 1970). The 65% juveniles collected in southwestern Wisconsin agrees with reports of juveniles ranging from 41% to 70% of the harvest in northern areas (Stuewer 1943a,b, Sanderson 1951, Llewellyn 1952), and reflects differences in productivity, greater mortality from severe winters, intensive hunting and trapping pressure, and disease noted in northern areas over southern raccoon ranges (Johnson 1970).

The maximum longevity of raccoons collected in southwestern Wisconsin from 1978-80 approached 10 years. Wild raccoons may live up to 16 years (Garrett and Goertz 1975) but this is not realized under the current intensive hunting and trapping pressure in southwestern Wisconsin. The net reproductive value indicated that the raccoon population was declining during this investigation.

MANAGEMENT RECOMMENDATIONS

Raccoon pelts have increased markedly in value over the past few years. Wisconsin furbuyers paid an average of $32.33 for each raccoon hide purchased during the 1979-80 season (Wisconsin Dep. Nat. Resour. 1980). This was about 11 times greater than the average price paid from 1963-72 (Wisconsin Dep. Nat. Resour. 1976a). Compounded by a decline in the hunting opportunities for upland game birds due to dwindling habitat, hunting and trapping of raccoons has risen sharply over the last few years in Illinois (Hubert 1979) and other states. These factors have combined to provide the highest annual raccoon harvests ever documented in Wisconsin (Fig. 1).

My results indicate that raccoons in southwestern Wisconsin have been overharvested recently. Such high harvest rates cannot be maintained for a sustained annual yield in southwestern Wisconsin, but a drop in fur prices apparently will reverse this trend. A regression analysis of the 1970-80 raccoon harvests with corresponding annual pelt values was highly significant ($\underline{P} < 0.05$, r=0.76). However, if pelt values again reach the highs of the late 1970's, high harvests of raccoons are expected, and the following management recommendations should be considered.

Although bag limits often receive strong public support for regulating the harvest of furbearers, their true function is to distribute the harvest more equitably among hunters and trappers, rather than reduce overall take (Hubert 1979). However, many states have imposed bag limits with the idea of reducing the harvest of raccoons, with varying degrees of success. Three states believe that bag limit restrictions have no influence on total harvest, and 2 others did not know the effect (Hubert 1979). Hubert (1979) determined that a bag limit of 25 raccoons per season would fail to significantly reduce the annual harvest of over 249,000 raccoons in Illinois (Hubert 1977, 1978) because only 17% of the Illinois raccoon hunters and trappers harvest more than 25 raccoons per season. Establishing a limit with any type of pelt tagging program would cost almost $188,000 (Hubert 1979). Enforcement would be difficult because a hunter or trapper could license each family member and then harvest 25 raccoons per license.

A more suitable technique for manipulating the raccoon harvest involves changing season lengths and varying the opening dates, Season changes could be made through routine administrative procedures, cost little, and are easier to enforce (Hubert 1979). The present hunting and trapping season in Wisconsin extends from about 15 October through 31 January. When harvest pressure is low, seasons could extend during this entire period to increase the overall harvest of raccoons. Raccoons are more apt to be harvested by conventional methods during periods of above-freezing temperatures without snow because they are normally more active (Johnson 1970), Hubert 1979). When harvest pressure is high, seasons extending from 1 November through 31 January could be used to reduce the total harvest of raccoons while maintaining that harvest on a sustained annual yield basis. An opening date of 1 November would coincide with the start of red fox and gray fox hunting and trapping, and would reduce the illegal harvest of foxes that occurs during the early October raccoon season. Also, raccoons are not fully prime in Wisconsin before 1 November (V. Dobbs, furbuyer, pers. commun.). Because a mature female and many of her offspring are still traveling together during late October (Kellner 1953, Johnson 1970), delayed opening of the season would reduce the harvest of entire family groups (Johnson 1970).

Season reductions made by eliminating days at the end of the season tend to reduce the catch of highly successful raccoon harvesters (those taking >25 raccoons per season) more than the average harvester because the former are more likely to operate throughout the entire season (Hubert 1979). Therefore, they are not recommended unless a substantial reduction in the harvest of raccoons is desirable.

FUTURE RESEARCH

My analysis of the productivity and mortality of raccoons in southwestern Wisconsin has indicated a number of areas where future research is needed. Raccoons should be live-trapped (Berchielli and Tullar 1980), sexed, aged (Root 1981a), ear-tagged, radio-collared, and released within a designated study area of the state, in order to investigate spring and summer sex ratios, reproduction, and annual survivorship and mortality patterns. Special emphasis should be placed on determining the extent and magnitude of disease through superficial examination of live-trapped animals and necropsy of carcasses collected from furbuyers during the fall trapping season.

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Table 1. Age-related litter size[a] and percentage of barren females for 214 raccoons from southwestern Wisconsin, 1978-80.

Age (years)	Sample N	Percent barren	Mean litter size	Mean no. young per female	Range
1.5	72	68.0	3.65	1.17	1-5
2.5	60	11.7	3.57	3.15	1-6
3.5	31	9.7	3.68	3.32	1-6
4.5	21	4.8	3.45	3.29	2-6
5.5	11	18.2	4.11	3.35	2-6
6.5	8	0.0	3.38	3.38	2-4
7.5	6	0.0	3.67	3.67	2-5
8.5	5	0.0	4.60	4.60	2-7
Total	214	28.9	3.71	2.64	1-7
2.5+	142	9.2	3.72	3.38	1-7

[a] From placental scar counts.

Table 2. Birth and conception dates of 12 raccoon litters in southwestern Wisconsin, 1979.

Raccoon number	Sex	Date of capture	Age[a] (months)	Date of birth	Date of conception[b]
R2060	F	10/29	1.5 - 2.0	9/1-15	7/1-15
R2073	M	10/29	3.0 - 3.5	7/15-31	5/15-31
R2084	F	10/29	2.0	8/20-30	6/20-30
R2106	M	10/30	1.5 - 2.0	9/1-15	7/1-15
R2178	M	Late Oct	1.5 - 2.0	mid Sept	mid July
R2229	M	11/13	3.0 - 3.5	8/1-15	6/1-15
R2231	M	11/13	3.0 - 3.5	8/1-15	6/1-15
R2373	M	11/13	3.0 - 3.5	8/1-15	6/1-15
R2440	F	Early Nov	3.0 - 3.5	8/1-15	6/1-15
R2616	M	Early Nov	3.0 - 3.5	8/1-15	6/1-15
R2621	M	Early Nov	3.0 - 3.5	8/1-15	6/1-15
R2685	M	Oct - Nov	3.0 - 3.5	Unknown	Unknown

[a] Determined by tooth replacement (Montgomery 1964).

[b] A 63-day gestation period was assumed (Whitney and Underwood 1952).

Table 3. Chi-square comparison of the sex ratio (M:100F) of raccoons by method of capture and age.

Method and age	Sample N	M:100F	X^2
Hunted			
Juvenile	297	108	0.42
Adult	165	96	0.04
Combined	462	103	0.14
Trapped			
Juvenile	353	110	0.82
Adult	190	92	0.34
Combined	543	103	0.08
Unknown			
Juvenile	206	142	6.29^{*}
Adult	128	103	0.03
Combined	334	126	4.32^{**}
Combined juvenile	856	116	4.78^{**}
Combined adult	483	96	0.17
Overall	1,339	109	2.26

* Significant at $P = 0.025$, 1 df.

** Significant at $P = 0.05$, 1 df.

Table 4. Composite life table for raccoons from southwestern Wisconsin, 13 October - 31 January 1978-80.

Age (years) x	No. alive l_x	No. alive (Per 1000) l_x	No. Dead d_x	Mortality rate q_x	Mean expectation of further life (years) e_x
0.5	875	1000	797	0.797	1.053
1.5	178	203	49	0.241	2.224
2.5	135	154	64	0.415	1.773
3.5	79	90	47	0.411	1.678
4.5	38	43	14	0.326	1.965
5.5	26	29	13	0.448	1.676
6.5	14	16	5	0.313	1.625
7.5	10	11	6	0.545	1.136
8.5	4	5	3	0.600	0.900
9.5	2	2	2	1.000	0.500
Total	1,361	1,553	1,000	0.644	1.356
Adult	486	553	203	0.367	1.903

Table 5. Age composition of raccoons from southwestern Wisconsin, 1978-80.

Type of mortality	Sample N	Percent juveniles
Hunted	462	64
Trapped	543	65
Vehicle kill	22	86
Unknown	334	62

Table 6. Calculation of net reproductive rate (R_o) for raccoons from southwestern Wisconsin, 1978-80.

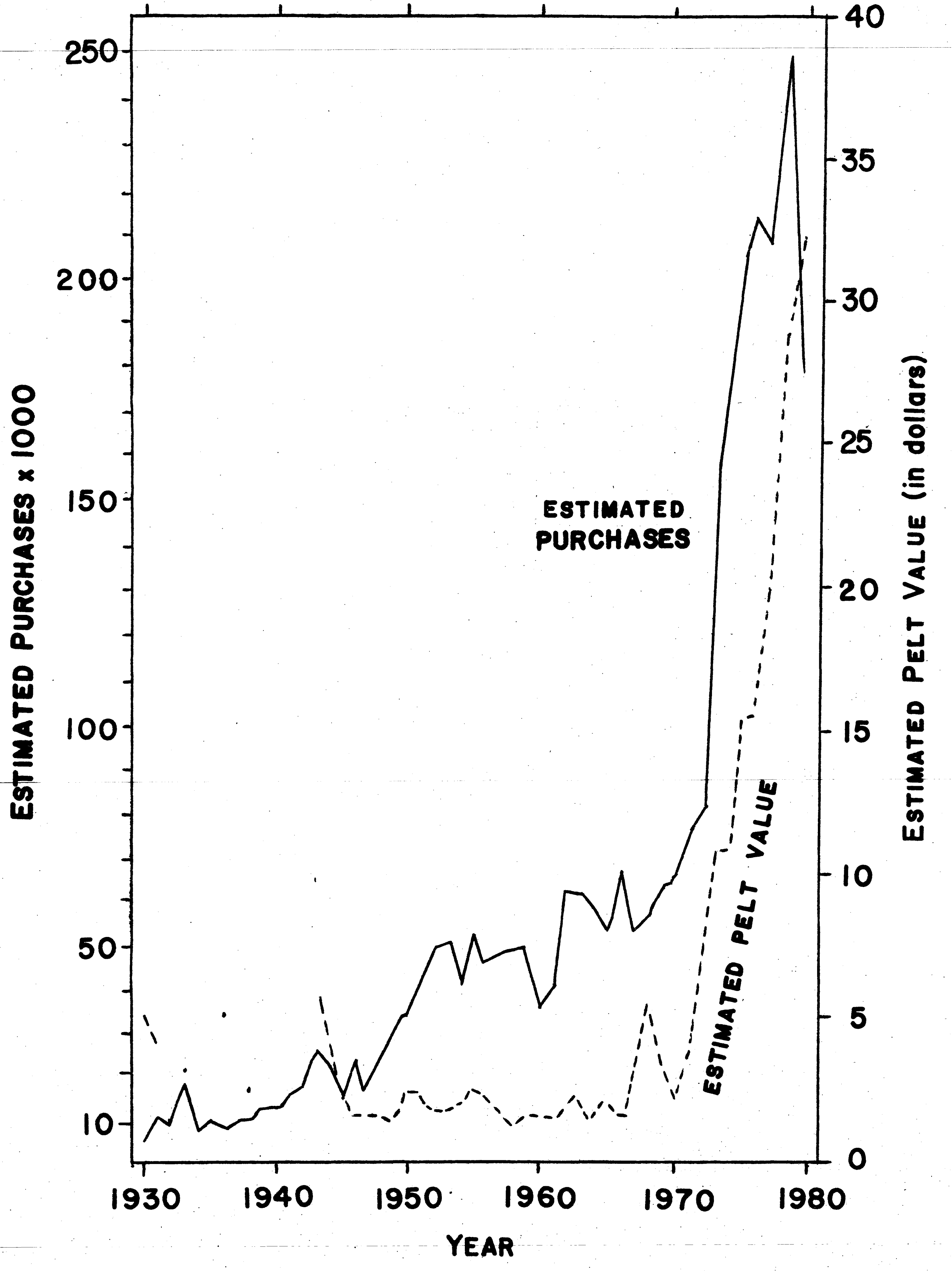
Age (years) x	Sample l_x	Per 1000 l_x	Natality m_x[a]	Reproductive rate $l_x m_x$
0.5	405	1.00	0.00	0.00
1.5	86	0.21	0.59	0.12
2.5	63	0.16	1.58	0.25
3.5	40	0.10	1.66	0.17
4.5	24	0.06	1.65	0.10
5.5	14	0.04	1.68	0.07
6.5	7	0.02	1.69	0.03
7.5	7	0.02	1.84	0.04
8.5+	6	0.02	2.30	0.05
				0.83 = R_o

[a] A sex ratio of 50:50 at birth was assumed.

Table 7. Sex ratio (M:100F) of raccoons from various regions of the United States.

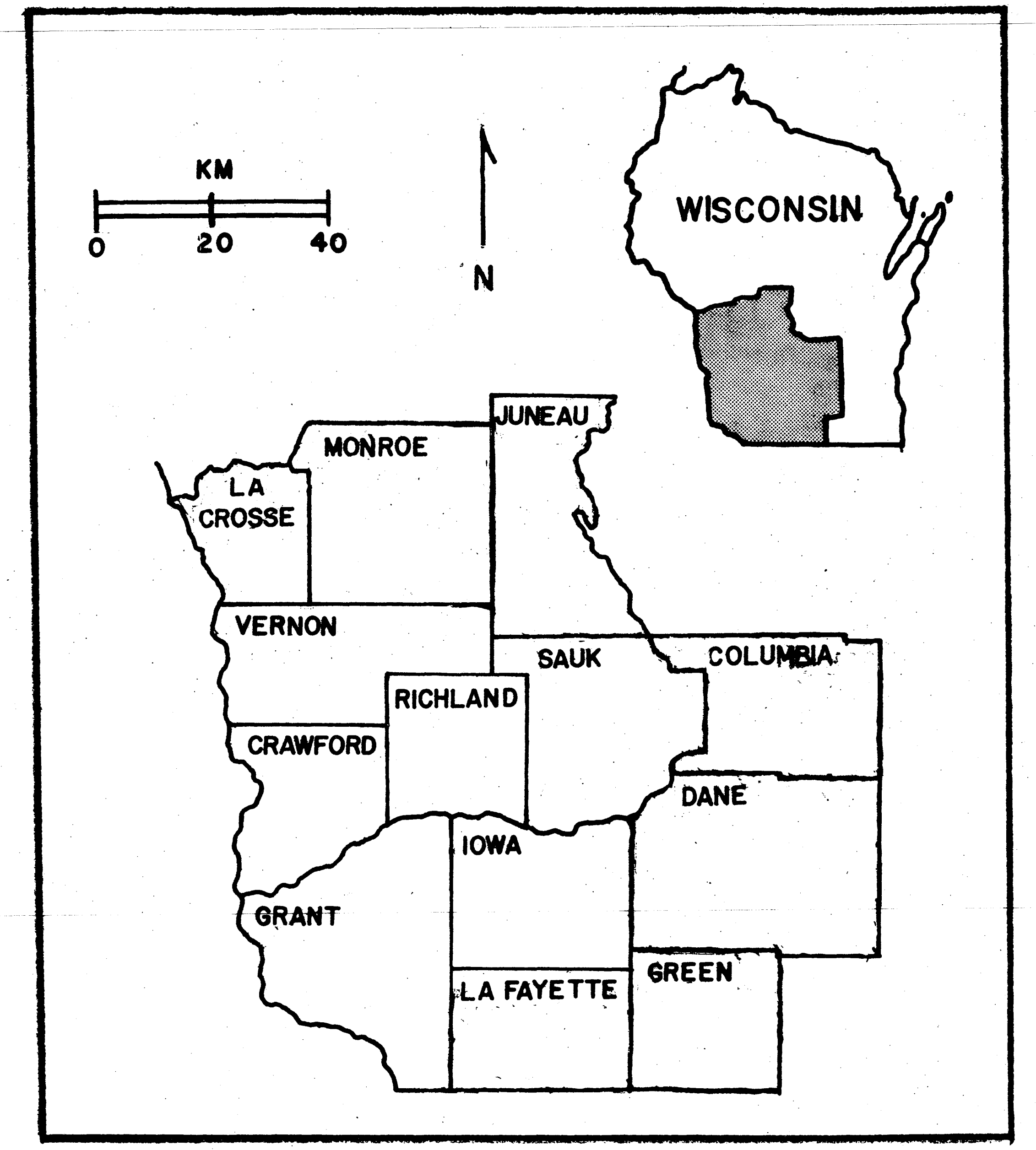
State	M:100F	Sample N	Reference
Alabama	168	1,222	Johnson 1970
Arkansas	100	256	Giles 1943
Kansas	150	918	Stains 1956
Maryland	80	492	Llewellyn 1952
Michigan	108	256	Stuewer 1943b
Missouri	127	306	Bennitt and Nagel 1937
Missouri	150	10,769	Noren 1941
Missouri	100	956	Sanderson 1951
Ohio	126	132	Preble 1941
South Carolina	140	223	Cunningham 1962
Washington	98	127	Scheffer 1950
SW Wisconsin	109	1,339	Current study

Fig. 1. Estimated raccoon pelt purchases and corresponding pelt value from Wisconsin 1930-79, adapted from Wisconsin Dep. Nat. Resour. (1976_b_).



ESTIMATED PURCHASES x 1000
250
200
150
100
50
10
ESTIMATED PURCHASES
ESTIMATED PELT VALUE
ESTIMATED PELT VALUE (in dollars)
40
35
30
25
20
15
10
5
0
1930
1940
1950
1960
1970
1980
YEAR

Fig. 2. Raccoon study area of southwestern Wisconsin.


KM
0
20
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N
WISCONSIN
JUNEAU
MONROE
LA CROSSE
VERNON
SAUK
COLUMBIA
RICHLAND
CRAWFORD
DANE
IOWA
GRANT
GREEN
LA FAYETTE

Fig. 3. Monthly variations in the percentage of juvenile, yearling, and adult raccoons with sperm in the cauda epididymis. Sample sizes are listed above percent with sperm.

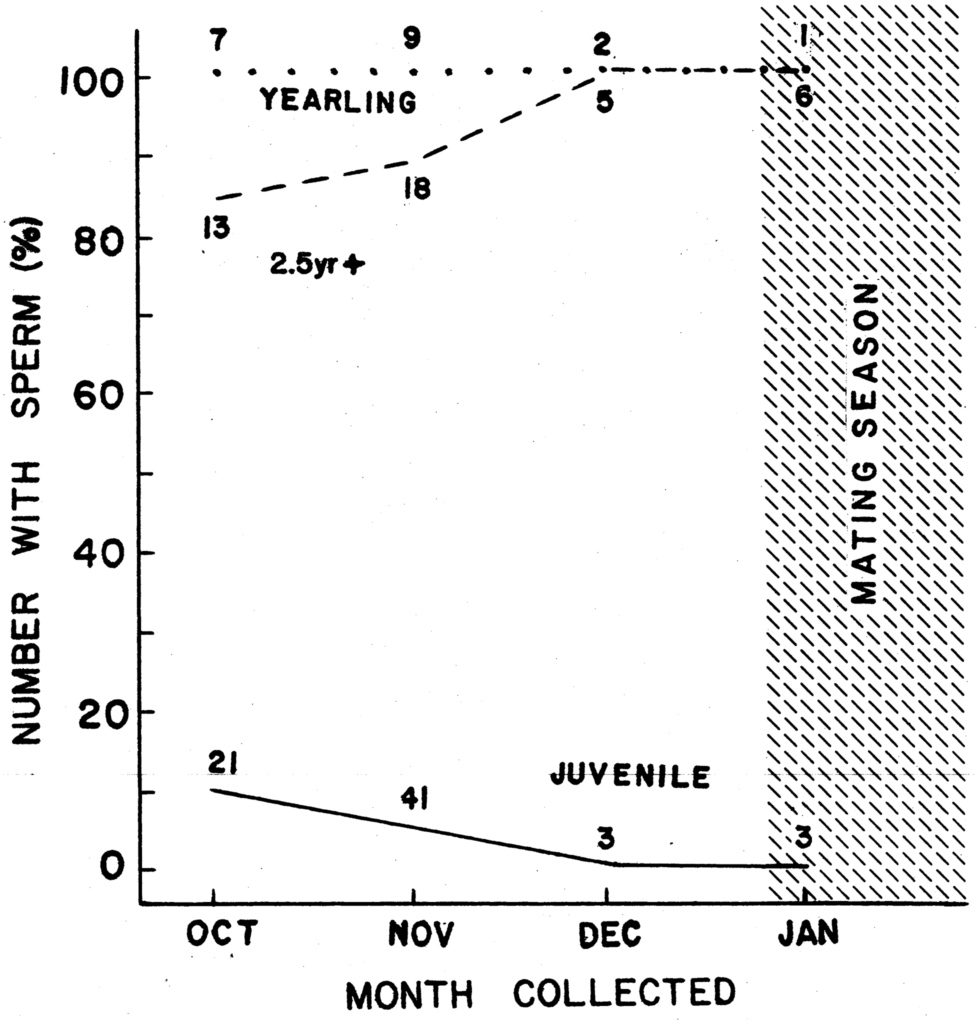
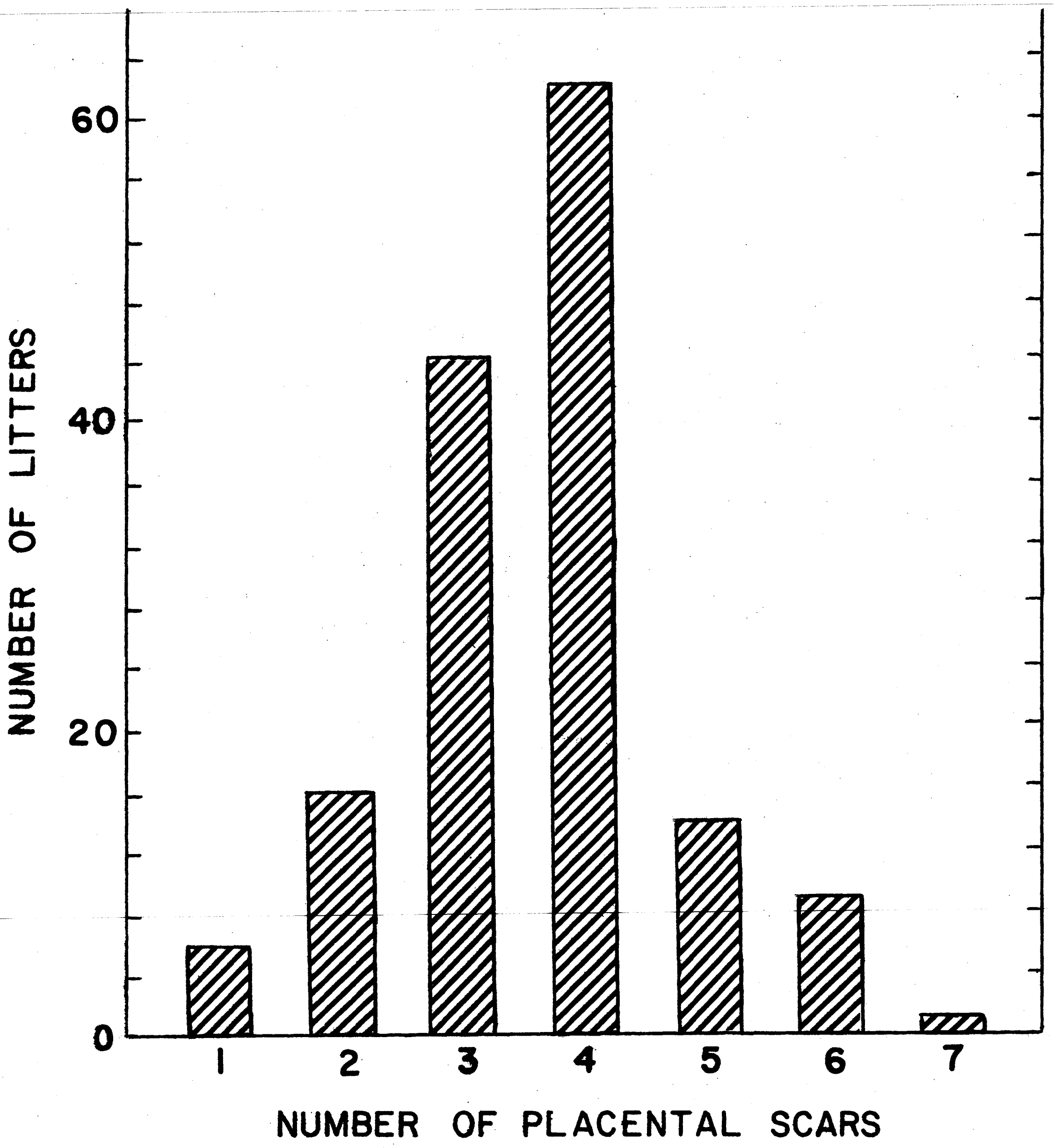

NUMBER WITH SPERM (%)
100
80
60
40
20
0
7
9
2
1
YEARLING
5
6
18
13
2.5yr +
MATING SEASON
21
41
JUVENILE
3
3
OCT
NOV
DEC
JAN
MONTH COLLECTED

Fig. 4. Placental scar counts of 152 raccoons from southwestern Wisconsin, 1978-80.



NUMBER OF LITTERS
60
40
20
0
1
2
3
4
5
6
7
NUMBER OF PLACENTAL SCARS

Fig. 5. Monthly variation in sample sex ratio (M:100F) in relation to age of 1,340 raccoons from southwestern Wisconsin, 1978-80. Numbers above bars indicate sample sizes for each age-class.

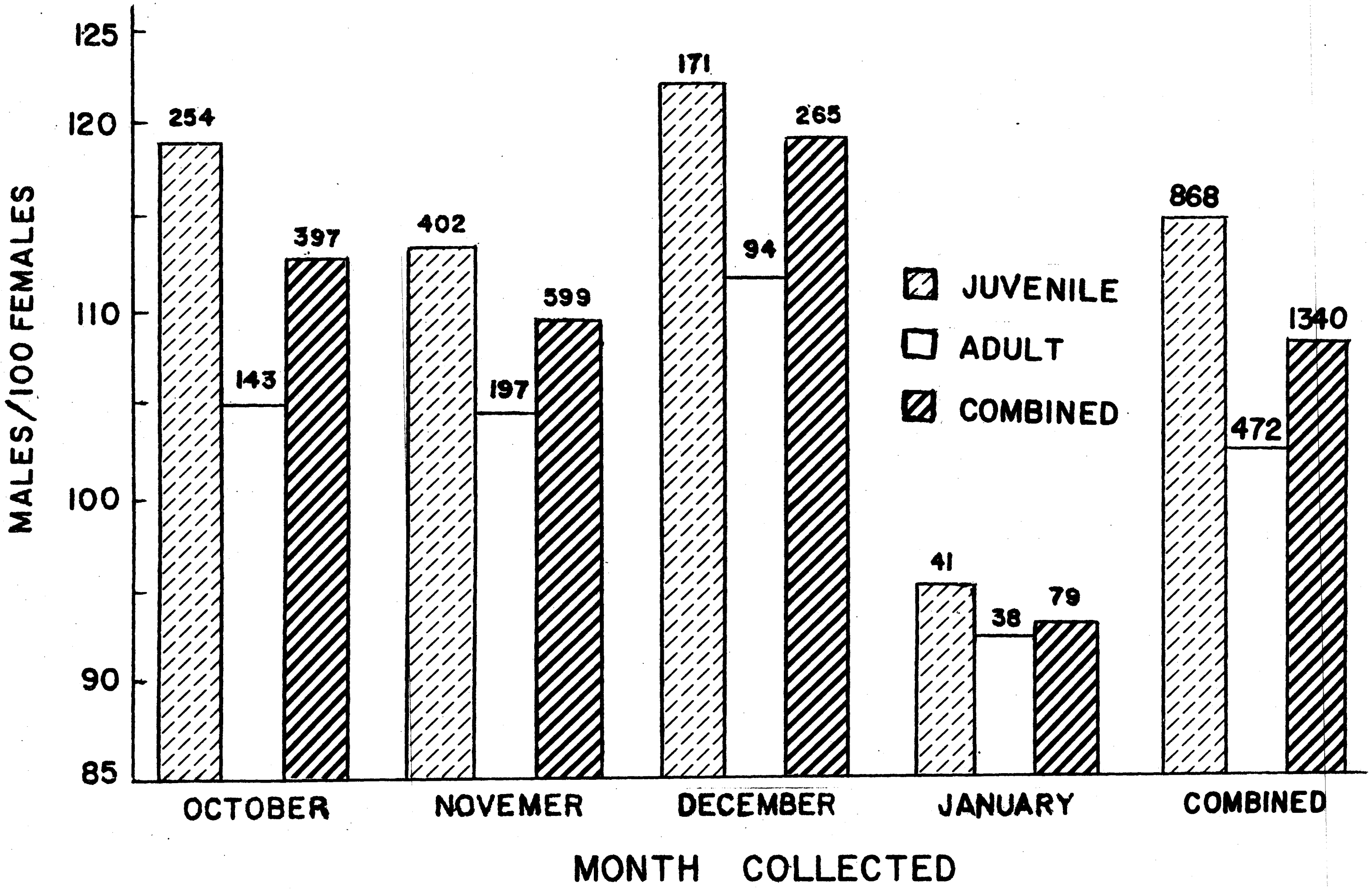

MALES/100 FEMALES
125
120
110
100
90
85
254
143
397
402
197
599
171
94
265
41
38
79
868
472
1340
JUVENILE
ADULT
COMBINED
OCTOBER
NOVEMER
DECEMBER
JANUARY
COMBINED
MONTH COLLECTED

Fig. 6. Age distribution (%) of raccoons from southwestern Wisconsin, 13 October - 31 January 1978-80. Numbers of each age group are listed along bars.

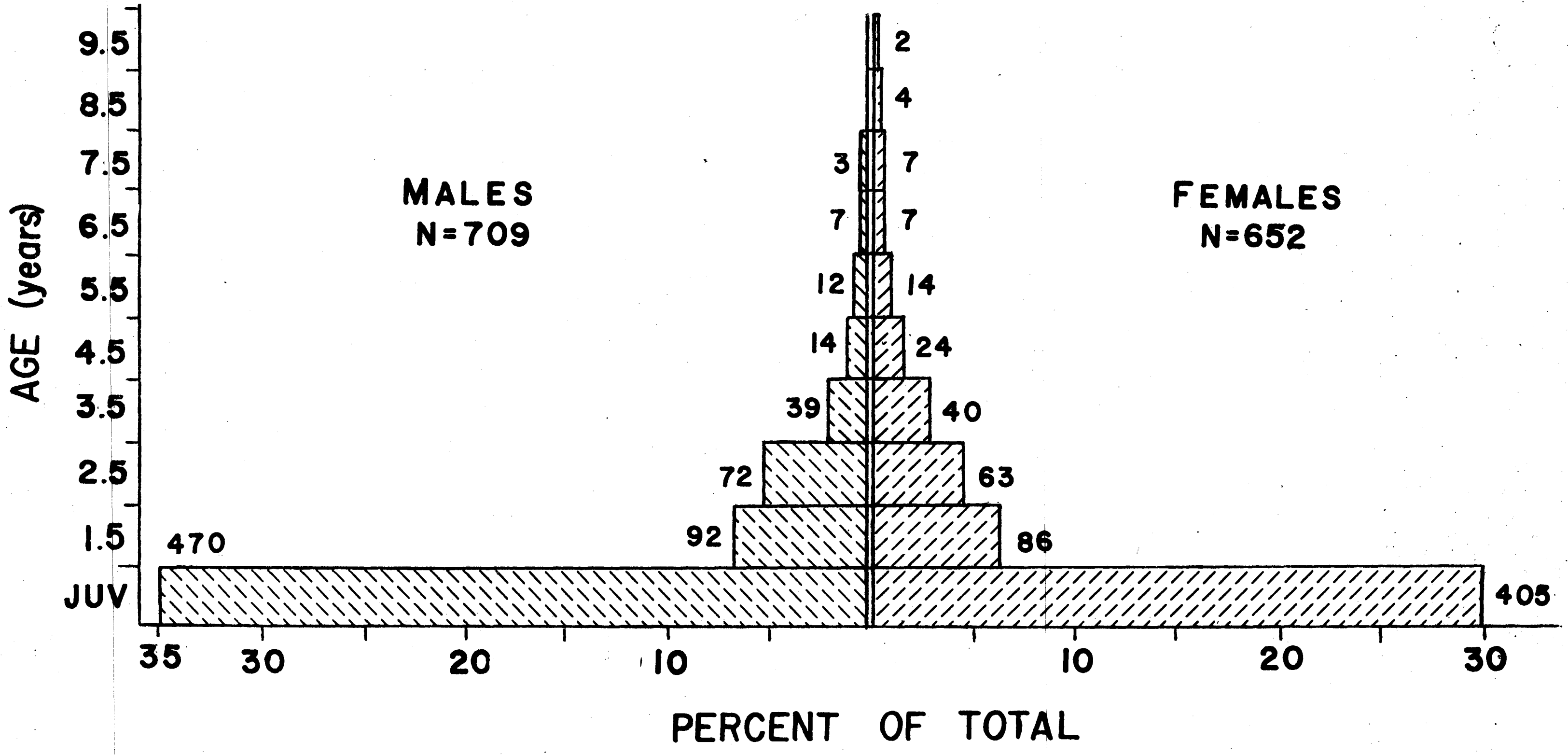

AGE (years)
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
JUV
MALES
N=709
FEMALES
N=652
2
4
3
7
7
7
12
14
14
24
39
40
72
63
92
86
470
405
35
30
20
10
10
20
30
PERCENT OF TOTAL

Fig. 7. Number of juveniles (%) by month and method of capture, for raccoons from southwestern Wisconsin, 1978-80. Numbers collected are in parentheses.

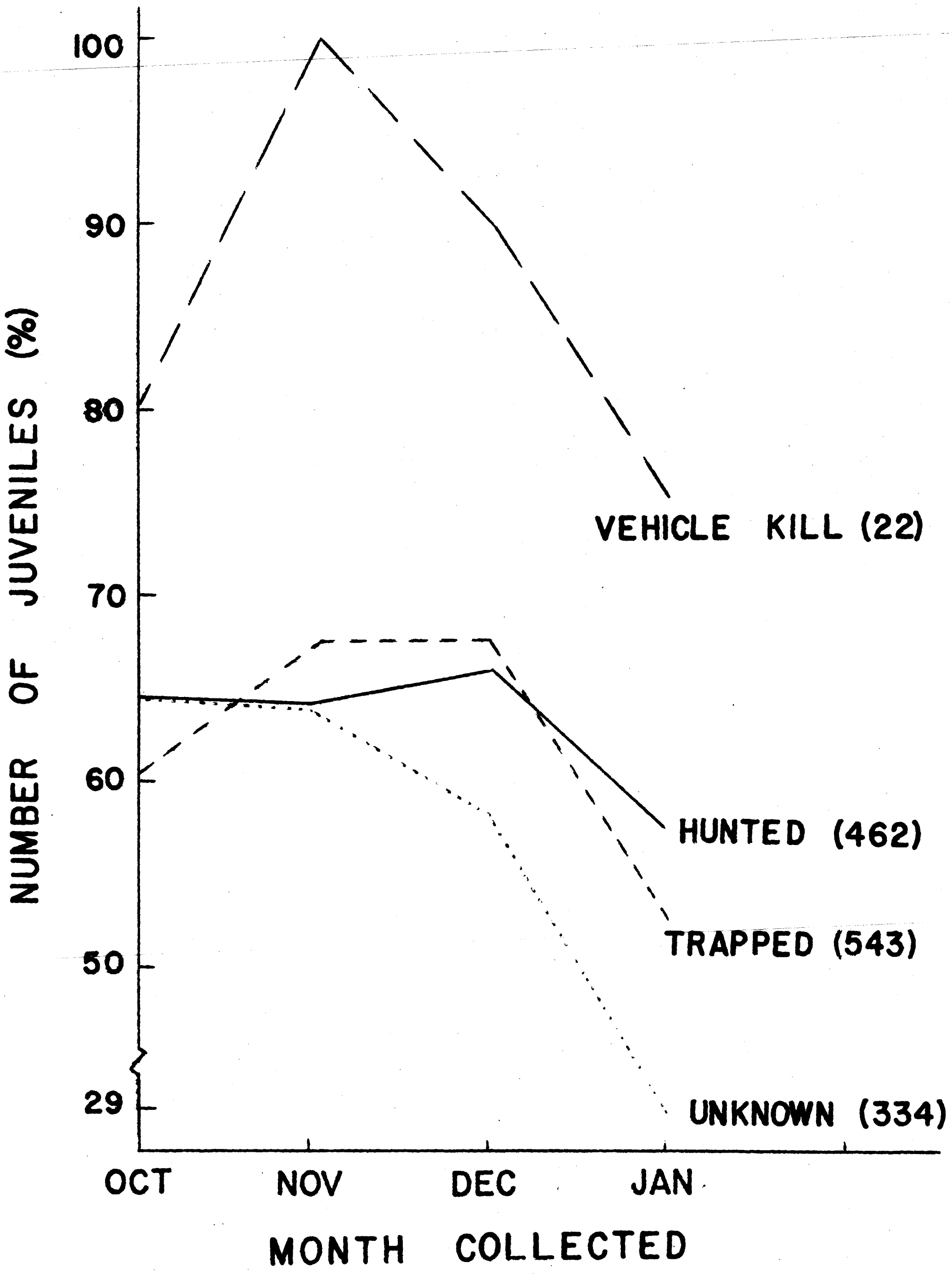

100
90
80
70
60
50
29
NUMBER OF JUVENILES (%)
VEHICLE KILL (22)
HUNTED (462)
TRAPPED (543)
UNKNOWN (334)
OCT
NOV
DEC
JAN
MONTH COLLECTED

Fig. 8. Survivorship curve of 1,361 raccoons from southwestern Wisconsin, 1978-80.

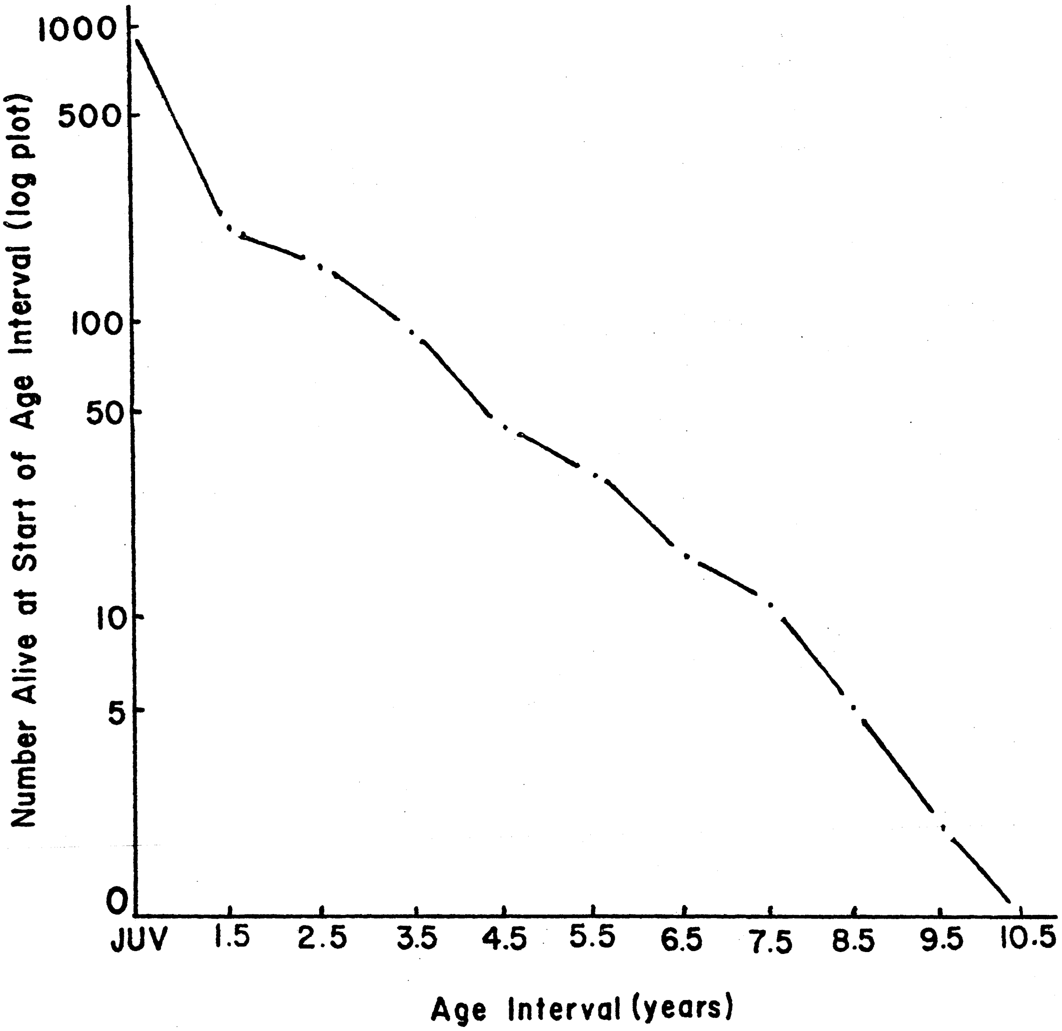
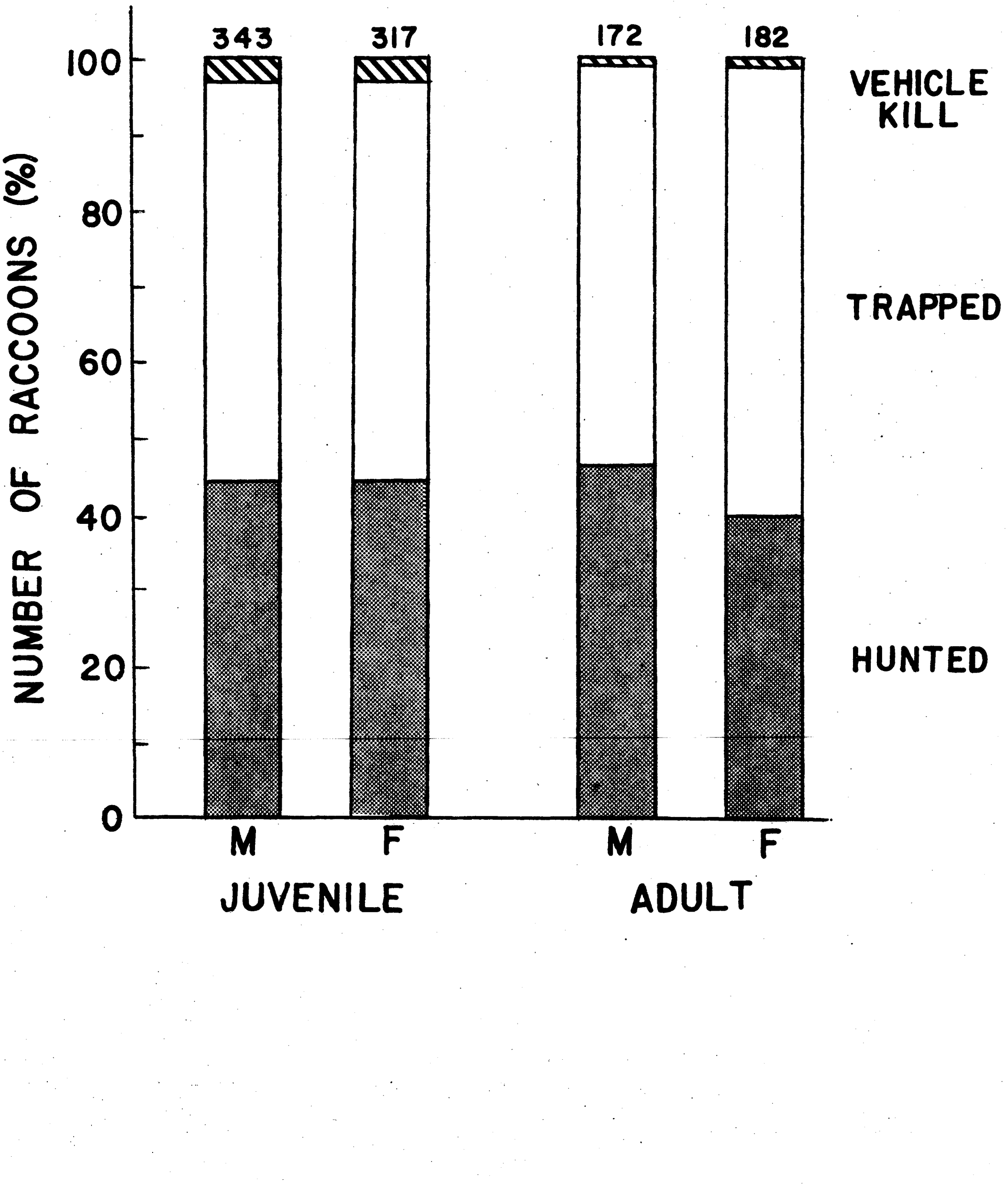

1000
500
100
50
10
5
0
Number Alive at Start of Age Interval (log plot)
JUV
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
Age Interval (years)

Fig. 9. Causes of death of 1,014 raccoons from southwestern Wisconsin, 13 October - 31 January 1978-80. Numbers above bars indicate sample sizes in each category.


343
317
172
182
100
80
60
40
20
0
NUMBER OF RACCOONS (%)
VEHICLE KILL
TRAPPED
HUNTED
M
F
M
F
JUVENILE
ADULT

Appendix A. A hybrid technique for aging gray foxes.

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RH: Technique for Aging Gray Foxes • Root

A HYBRID TECHNIQUE FOR AGING GRAY FOXES

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Abstract: Using subjective interpretations of upper canine roots, apical foramina, pulp cavity widths, and cementum annuli, a hybrid technique was used to determine the age of 648 gray foxes (*Urocyon cinereoargenteus*) collected in southwestern Wisconsin, 3 November - 31 January 1978-80. All 425 juveniles could be distinguished from adults by the presence of canine root apical foramina or canine pulp cavity widths $>40\%$ of maximum tooth width. Older animals were aged by counts of annular cementum layers of an upper canine tooth. Although about 75% of the juvenile gray foxes could be distinguished from adults by total enamel line measurements <2.0 mm or tooth wear patterns, the hybrid technique is faster, simpler, and appears to be 100% accurate. However, cementum annuli age estimates of adults must be used cautiously until verified with an adequate sample of known-age animals.

J. WILDL. MANAGE.

Key words: aging, gray foxes, southwestern Wisconsin, *Urocyon cinereoargenteus*.

The lack of suitable aging techniques has hampered studies of population dynamics and productivity in gray foxes. Past studies have used the degree of ossification of the radius and ulna (Sullivan and Haugen 1956), tooth wear patterns (Wood 1958), pelage, body weights, and eye lens weights (Wood 1958, Lord 1961) to distinguish juvenile from adult gray foxes, but all have associated problems. Bone ossification, body weights, and pelage characteristics are reliable indicators of age only from birth through October of the 1st year of life. Rates of tooth abrasion are known to vary markedly between areas (Bree et al. 1974). The problems associated with eye lens collection (Montgomery 1963, Friend 1967a,b) and preservation (Friend 1976b) require further understanding before accurate age estimates can be obtained (Friend 1968).

Stone et al. (1975) used Romanowsky stains to define cementum annuli in gray fox tooth sections. Although counts of annuli of 5 known-age gray foxes from Alabama support the technique (Nicholson and Hill 1980), sample sizes of known-age material are small (Dapson 1980). The objectives of this study were to determine (1) if cementum annuli procedures are valid for age determination of gray foxes, and (2) the comparative values of tooth wear, presence of canine root apical foramina, canine pulp cavity widths, and enamel line measurements as aging criteria.

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supplied carcasses for this project. Financial support was provided by the University of Wisconsin-Stevens Point.

METHODS

Molar Wear

Carcasses of 648 gray foxes collected from trappers, hunters, and furbuyers in southwestern Wisconsin during the 1978-79 and 1979-80 trapping season (3 November - 31 January) provided material for study. The degree of wear on the protoconule and metaconule of the first upper molar was recorded (Wood 1958), and the distal portion of the upper mandible removed and stored frozen for processing 2 to 3 months later.

Enamel Line Measurements

Groups of 50 mandibles were thawed out daily and boiled for 20 minutes in a solution of 2 tablespoons of anhydrous potassium carbonate per 4 liters of water (Nellis et al. 1978). All tissue along the gumline was removed to expose the rims of the incisor, canine, and premolar alveolar sockets. The lateral surfaces of the upper canines were scratched with a knife to facilitate location of the enamel line (Macpherson 1969), and the distance from a line between the edges of the alveoli I3 and P1 on the labial side to the edge of the enamel on the posterior face of both canines (C1 drop) (Nellis et al. 1978) measured to the nearest 0.1 mm with a metric vernier caliper (Allen 1974). In cases where 1 canine was broken or appeared abnormal, the measurement of the other was doubled (Allen 1974). Teeth were then extracted and the upper right canine decalcified in a solution of 3.67% HCL for 20 hours. If the upper right canine was missing, the upper left canine or either of the upper premolars was substituted.

Canine Root Apical Foramen - Pulp Cavity Measurement

After decalcification, the root tip was examined for the presence of a visible foramen. Misclassification of a canine foramen was minimized by gently squeezing the tooth so the fluid within the pulp cavity would seep out of the root tip if an open foramen was present. The crown was then severed at the gumline and, for canines, measurements taken of the maximum pulp cavity and total tooth width to the nearest 0.1 mm with a metric vernier caliper. Pulp cavity width was calculated as a percentage of maximum tooth width (Grue and Jensen 1976, B. Jensen, unpubl. data).

Cementum Annuli

Longitudinal tooth sections were cut at 16μ with a cryostat set at -22C, placed on glass slides, dried for 1 hour at room temperature, and originally stained with fresh giemsa (Stone et al. 1975). When it became apparent that giemsa did not consistently stain annuli, even after increased stain concentrations and durations, hematoxylin and eosin were used. Problems with giemsa were noted in the laboratory with tooth sections from raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), and black bears (*Ursus americanus*). Slides were mounted in Permount and examined on 3 separate occasions; the concensus of ages assigned was taken as the actual age, adding 1/2 year to compensate for the time from birth to harvest during the fall trapping season.

Except for 1 gray fox with deciduous upper canines wedged behind the permanent ones, gray foxes of known-age were not available for use in verifying the cementum annuli techniques used in this study. Nicholson and Hill (1980) suggested that gray foxes annually deposit 1 annulus sometime from March through May during the 1st year of life, and 1 line annually thereafter; however, their conclusions were based on only 5 known-age animals, which Dapson (1980) argues is an insufficient sample size of known-age material.

To establish the age when gray foxes initially deposit 1 or more annuli, I compared the number of dark-stained bands in the cementum of a canine from each female gray fox to its reproductive status as determined by uterine analysis. Female gray foxes breed for the first time at about 9 to 10 months of age and give birth about 53 days later (Layne and McKeon 1956, Wood 1958). Uteri of postpartum vixens would contain placental scars whereas those of juveniles would not. Barren adult females have been distinguished from juveniles by uterine size and coloration through October (Layne and McKeon 1956), and these criteria were applied to my southwestern Wisconsin sample. I assumed that a similar rate of annular deposition would occur for both sexes.

RESULTS AND DISCUSSION

Verification of Cementum Annuli

Reproductive status as determined from placental scar counts and size and condition of the uterus were assumed to provide a reliable substitute for known-age gray foxes in determining when the 1st annulus was formed. One or more dark-stained annuli were observed in the canine cementum of all females for which uterine placental scars were present (Table 1). However, 13 vixens with canine bands were without uterine scars. Layne and McKeon (1956) classified them as barren adults. None of 214 females with creamy white or thin, translucent reproductive tracts <3 mm in diamter, which were classified as juveniles (Richards and Hine 1953, Layne and McKeon 1956), possessed canine cementum bands.

If gray foxes breed for the first time at about 9 to 10 months of age, as suggested by Sheldon (1949), Layne and McKeon (1956), and Wood (1958), the above comparison of uterine condition and number of cementum bands indicates that at least 1 dark-stained band is formed during the fox's 1st year of life. Evidence from 1 southwestern Wisconsin gray fox showed that only 1 annulus was being deposited in the cementum when it was killed in early March.

Comparable studies of red foxes (Jensen and Nielsen 1968, Grue and Jensen 1973, Monson et al. 1973, Allen 1974), arctic foxes (*Alopex lagopus*) (Grue and Jensen 1976), sledge dogs (*C. familiaris*) (Grue 1976), and many other animals (Klevezal and Kleinenberg 1967, Fancy 1980) have all shown that 1 line is formed annually, including during the 1st year of life. Furthermore, Kolb (1978) determined that yearly deposition of 1 annulus results from endogenous factors correlated with the annual reproductive cycle, and not in response to winter food shortages or severe climatic conditions, as others have suggested

(Klevezal and Kleinenberg 1967, Grue and Jensen 1976, Grue 1976).

For coyotes, deposition of the 1st annulus occurs during the 2nd year of life (Linhart and Knowlton 1967, Nellis et al. 1978), when they become sexually active for the first time (Gipson et al. 1975). The gray fox, which breeds once each year from late February through March in Wisconsin (Richards and Hine 1953, Jackson 1961), should therefore deposit 1 annulus each year in the cementum from its 1st reproductive season through death.

With the overwhelming amount of information supporting the annual deposition of annuli, I agree with Nicholson and Hill (1980) in concluding that gray foxes annually deposit 1 annulus in the dental cementum from their 1st reproductive season through death. My annuli procedures accurately distinguish juvenile from adult gray foxes from southwestern Wisconsin (Table 1); however, cementum annuli age estimates of adults must be used cautiously until verified with an adequate sample of known-age gray foxes.

Characteristics of Annuli

Annuli counts were taken along the root apex of premolars and gingival line for canines, where maximum numbers could be distinguished. Although annuli counts from red fox (Allen 1974), arctic fox (Grue and Jensen 1976), and coyote (Roberts 1978) canine tooth sections are best taken along the root apex, comparable regions in gray foxes are faded and annuli are poorly defined. Bands are clearly outlined and easily interpreted along the sides of the tooth, however.

Annuli counts from premolars and canines agreed in 96% of 25 gray foxes examined, indicating a similar rate of deposition in both teeth.

No difficulty in the interpretation of annuli was apparent. Only 10 of 224 adult animals were inconsistently aged when viewed on 3 separate occasions. All estimates were plus or minus 1 year. False, split, and compound annuli (Lockard 1972, Rice 1980) were not observed with canine tooth sections although they were evident in premolar teeth. Consequently, annuli counts should be taken along the gingival line of an upper canine tooth section when possible. When canines are missing, an upper 1st premolar can be substituted, but care must be taken to distinguish irregular tooth structures (Rice 1980).

Other Aging Techniques

Ages assigned to 648 gray foxes based on cementum annuli techniques were assumed to represent the actual age of the animals, and were used to evaluate the accuracy of less time-consuming procedures for distinguishing juveniles from adults.

Canine Root Apical Foramen

The presence of a canine root apical foramen has been used effectively to distinguish juvenile from adult furbearers in the past. Grau et al. (1970) could separate all juvenile raccoons $<$ 12 months old by the presence of an open canal. Similarly, Nellis et al. (1978) concluded that all coyotes $<$ 8 to 9 months of age have open foramina. Although Wood (1958) examined tooth replacement and wear patterns of gray foxes from Georgia and Florida, he made no mention of using foramina to identify juvenile animals.

Gross examination of upper canine teeth from southwestern Wisconsin gray foxes revealed that 49% of 366 juveniles could be separated from adults by the presence of a canine foramen (Fig. 1). During November, 65% of 220 juveniles had open root canals; by late December that figure decreased to about 30%. Although 22% of 56 gray foxes killed in January showed open foramina, 90% of 50 animals were harvested during the 1st week, and may actually have represented December rather than January. No adult had an open foramen.

Although canine foramina are clearly visible during November, they become progressively more difficult to distinguish from late December to early January. Misclassification of foramina was minimized by gently squeezing the decalcified tooth so the fluid within the pulp cavity would be forced out of the root tip if an open foramen was present. This process appears to have biased the results (Fig. 1) towards a greater percentage of gray foxes killed in December and January with open foramina. Recently closed foramina of an unknown number of animals may have actually broken open when pressure was applied, thus classifying them as open. However, because no adults were incorrectly aged by this procedure, the technique appears valid for rapidly separating juvenile from adult gray foxes.

Pulp Cavity Size

Grue and Jensen (1976) and B. Jensen (unpubl. data) demonstrated the possibility of using the canine pulp cavity of red foxes and arctic foxes to separate young-of-the-year from older animals. This method was applied to teeth of 541 southwestern Wisconsin gray foxes. The pulp cavity width of each animal was expressed as a percentage of maximum tooth width, and plotted against month of death (Fig. 2).

In Wisconsin, gray fox pups are born during May (Richards and Hine 1953, Jackson 1961), and permanent canines erupt at about 5 to 5.5 months of age (Wood 1958). From late October to early November the width of the pulp cavity forms about 61% of total tooth width (Fig. 2). During the next 2 months the percentage decreases slightly to about 53% by late January. Mean pulp cavity width for adults remains constant at around 17% during this period.

The data in Fig. 2 falls into 2 distinct groups; canines with pulp cavity widths exceeding 40% of the maximum canine tooth width, and those with a lesser value. For the entire late fall and early winter collection period it was possible to separate young-of-the-year from older gray foxes on the basis of pulp cavity size. Further, percentage of pulp cavity size decreases with age of foxes (Table 2) so that in the future age-classes may be subdivided on the basis of pulp cavity size. Measurements of pulp cavity size were taken to the nearest 0.1 mm, but accuracy may be increased substantially by measuring the pulp cavity to the nearest 0.025 mm, and using the calculated percentage pulp cavity figures to separate older age groups.

Tooth Wear

Although tooth wear patterns have been used reliably to age coyotes (Gier 1968), wolves (*C. lupus*) (Gurskii 1973), and dogs (Silver 1969), rates of tooth abrasion are known to vary markedly between areas. Wood (1958) defined 5 degrees of tooth wear which he thought were correlated with estimated age. Bree et al. (1974) examined the wear techniques of Wood (1958) and Stubbe (1965) and found that only 35% of the red foxes examined from the Netherlands and 47% from France could be aged accurately. Harris (1978) could correctly age only 41% of 227 suburban London red foxes by tooth wear, when compared to ages assigned by cementum annuli techniques.

Tooth wear patterns of 540 southwestern Wisconsin gray foxes were also unreliable as an indicator of actual age. Considerable variability occurred in the degree of development of the molar cusps, and also the degree of wear. Invariably tooth wear was more pronounced on 1 side of the mouth than the other, and also in molars if adjacent teeth were broken or missing.

Characteristics for separating juvenile from yearling foxes were especially difficult. Animals with pitted conules on 1 side of the mouth (yearling character) often had sharp, pointed conules on the other side (juvenile character). Similarly, animals with pitted posterior conules and pointed anterior conules were common. No apparent wear patterns were evident.

Because the tooth wear age estimates of shot and trapped males and females showed no apparent differences in rates of attrition ($P > 0.05$), the data were combined and presented in Fig. 3. Log-log transformations were used to attain homoscedasticity by decreasing the variance in age estimates of the older age groups (Zar 1974, Dapson 1980, Earle and Kramm 1980). The slope, Y-intercept, and standard error of estimate indicate that tooth wear age estimates greatly overestimate the age of younger animals and underestimate the age of older foxes in comparison to ages estimated by cementum annuli. Only 64% of 540 animals were aged correctly by tooth wear patterns, and 91% were aged with 1 year error or less (Table 3). Although 75% of 351 juveniles were aged correctly, errors of up to 4 years were evident, making this technique unsuitable for aging gray foxes from southwestern Wisconsin.

Enamel Line Measurements

Enamel line measurements (ELM) have proven useful in separating juvenile from adult carnivores. Nellis et al. (1978) distinguished all 10 known-age juvenile coyotes by ELM. Allen (1974) found that 88% of 65 juvenile red foxes had measurements $<$2.0 mm; but geographic variations in red fox ELM were possible. Churcher (1960) suggested a breakoff point of 1.0 mm. Rabenberg and Hart (1979) found that 2% of 52 juveniles could be separated from adults if ELM were $<$0.6 mm.

Of 253 juvenile gray foxes examined from southwestern Wisconsin, 78% had total ELM $\leq$2.0 mm (Fig. 4). No adults had ELM $<$2.0 mm. Although Macpherson (1969) stated that ELM for female arctic foxes lag $<$1.0 mm behind those of males, this difference was not apparent for gray foxes (<u>P</u> $>$0.05). Churcher (1960) thought that individual year classes could be differentiated accurately with ELM, but this was not apparent with southwestern Wisconsin gray foxes (Fig. 4).

CONCLUSIONS

A comparison of uterine condition and corresponding cementum annuli age estimates of 312 female gray foxes from southwestern Wisconsin indicated that cementum annuli procedures accurately distinguished juvenile from adult foxes (Table 1), and may be valid for aging older animals (Nicholson and Hill 1980). Ages were assigned to 648 gray foxes by cementum annuli procedures, and then used to distinguish juveniles from adults by less time-consuming processes.

Tooth wear patterns are unsuitable for separating juvenile from adult gray foxes. Age-classes were difficult to distinguish, and only 75% of 351 juveniles were aged correctly. Similarly, enamel line measurements accurately aged only 78% of 253 juveniles.

A fast, simple hybrid technique that first distinguished juveniles by the presence of a canine root apical foramen, and then separates the remaining juveniles from adults by canine pulp cavity widths $>$40% of maximum tooth width, appears to be 100% accurate. Adults may be aged by tallies of annuli of upper canine teeth, but this should be used cautiously as an actual indicator of age until verified with an adequate sample of known-age material. Preliminary research in Alabama (Nicholson and Hill 1980) indicates that gray foxes annually deposit 1 annulus in the dental cementum from their 1st reproductive season through death, but sample sizes of known-age material were small.

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Received ______________________________.

Accepted ______________________________.

Table 1. Uterine condition and number of cementum bands in canine teeth of 312 female gray foxes from southwestern Wisconsin, 1978-80.

Condition of uteri	Sample	No. of bands		
	N	0	1	2+
Placental scars present; tract dark, discolored, and non-translucent, >5 mm diameter	85	0	44	41
Placental scars absent; tract dark, discolored, and non-translucent, >5 mm diameter	13[a]	0	12	1
Placental scars absent; tract pink and translucent or creamy white colored, <3 mm diameter	214	214	0	0

[a] Barren adult females (Layne and McKeon 1956).

Table 2. Age-related changes in mean pulp cavity size (%) of an upper canine tooth for adult gray foxes from southwestern Wisconsin, November - January 1978-80.

Age (years)	Sample N	Mean pulp cavity width (%)	SE	Range (%)
1.5	104	17.79	0.63	2-37
2.5	48	15.00	0.81	6-38
3.5	16	11.63	1.04	6-18
4.5	7	10.43	2.70	2-23
5.5	8	4.00	0.65	2- 6
6.5	2	3.50	1.50	2- 5

Table 3. Accuracy of age determination from tooth wear for gray foxes shot and trapped in southwestern Wisconsin, November - January 1978-80.

Error	Sample N	Total (%)
Aged correctly	343	63.5
One year error	146	27.1
Two years error	39	7.2
Three years error	7	1.3
Four years error	5	0.9
Total	540	100.0

Fig. 1. Relationship between month of capture and percentage of juvenile gray foxes with canine root apical foramina.

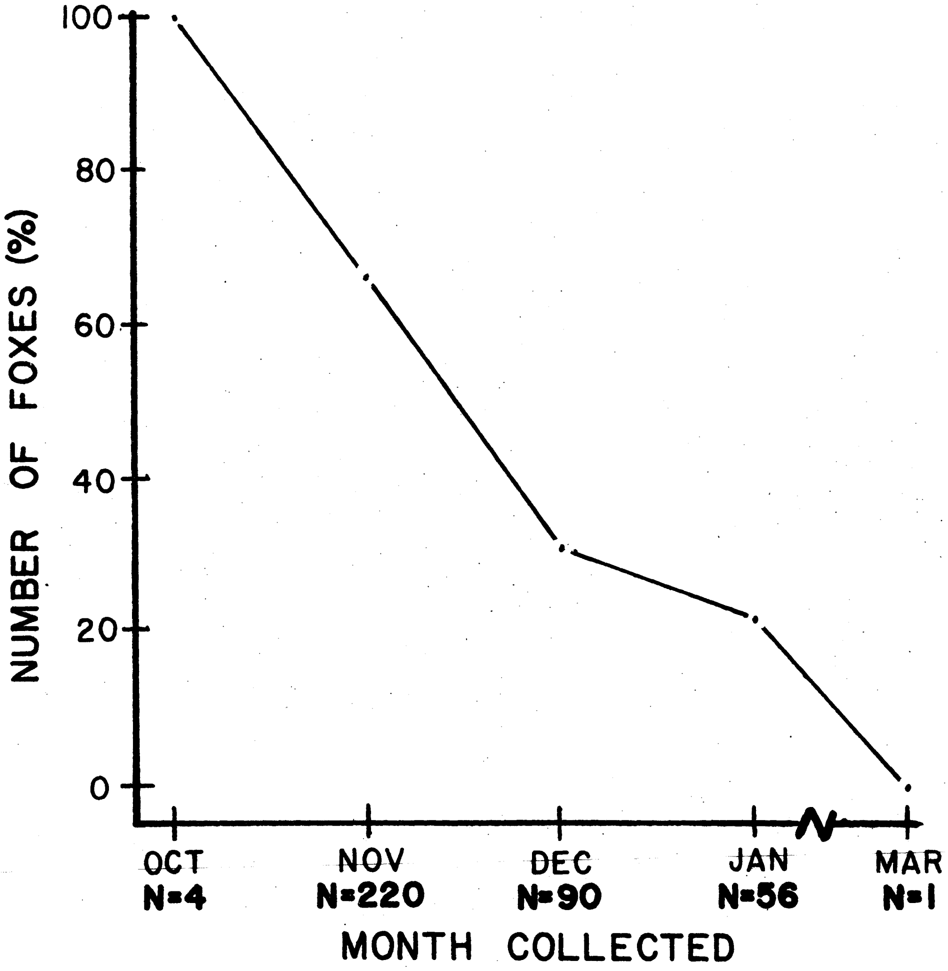

100
80
60
40
20
0
NUMBER OF FOXES (%)
OCT
N=4
NOV
N=220
DEC
N=90
JAN
N=56
MAR
N=1
MONTH COLLECTED

Fig. 2. Mean pulp cavity width as a percentage of maximum canine tooth width, in relation to month in which juveniles (dotted line) and adults (dashed line) were killed. Vertical lines represent range of percentages. Shaded rectangles are ± 1 SE. Numbers above vertical lines are sample sizes.

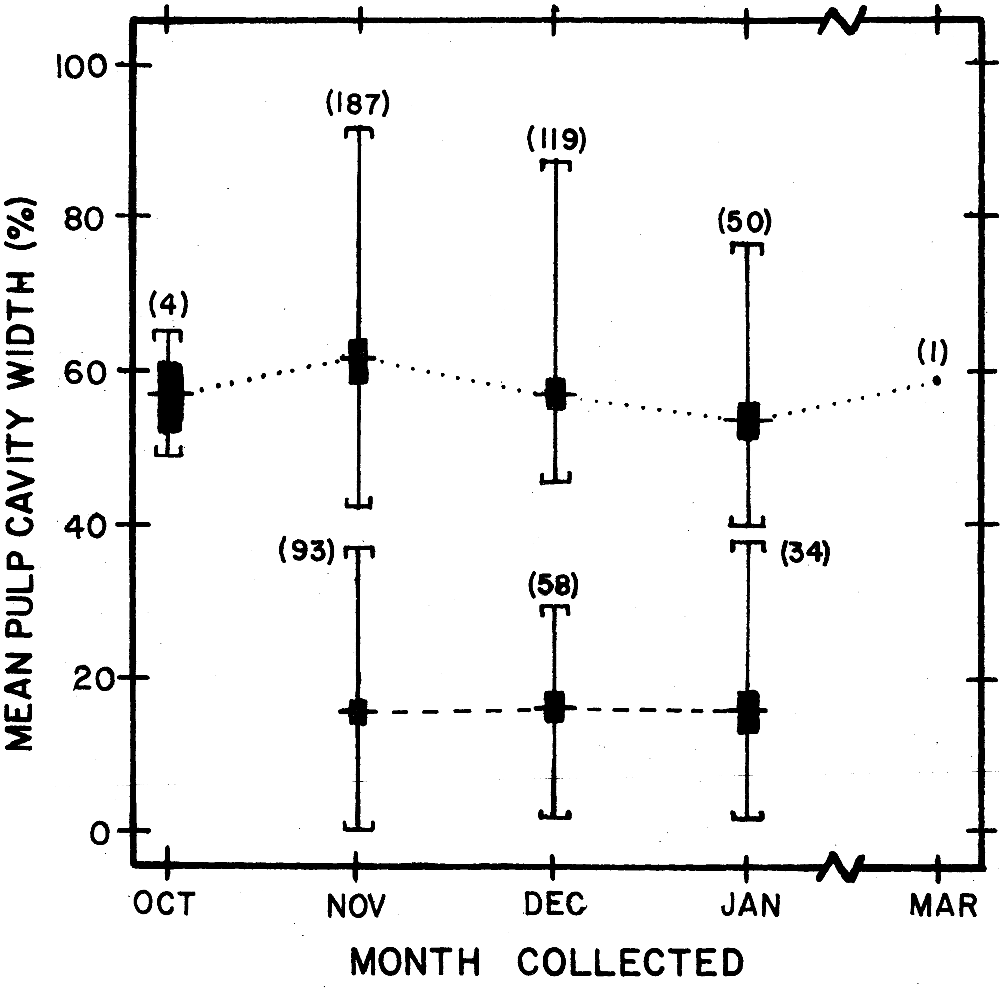

MEAN PULP CAVITY WIDTH (%)
100
80
60
40
20
0
(187)
(119)
(50)
(4)
(1)
(93)
(58)
(34)
OCT
NOV
DEC
JAN
MAR
MONTH COLLECTED

Fig. 3. Relationship between age estimated by cementum annuli counts and tooth wear patterns of 540 gray foxes from southwestern Wisconsin, November - January 1978-80. Numbers indicate sample sizes. The equation is log Y = log 0.549X + log 0.413, $r^2 = 0.348$, and SE = 0.830.

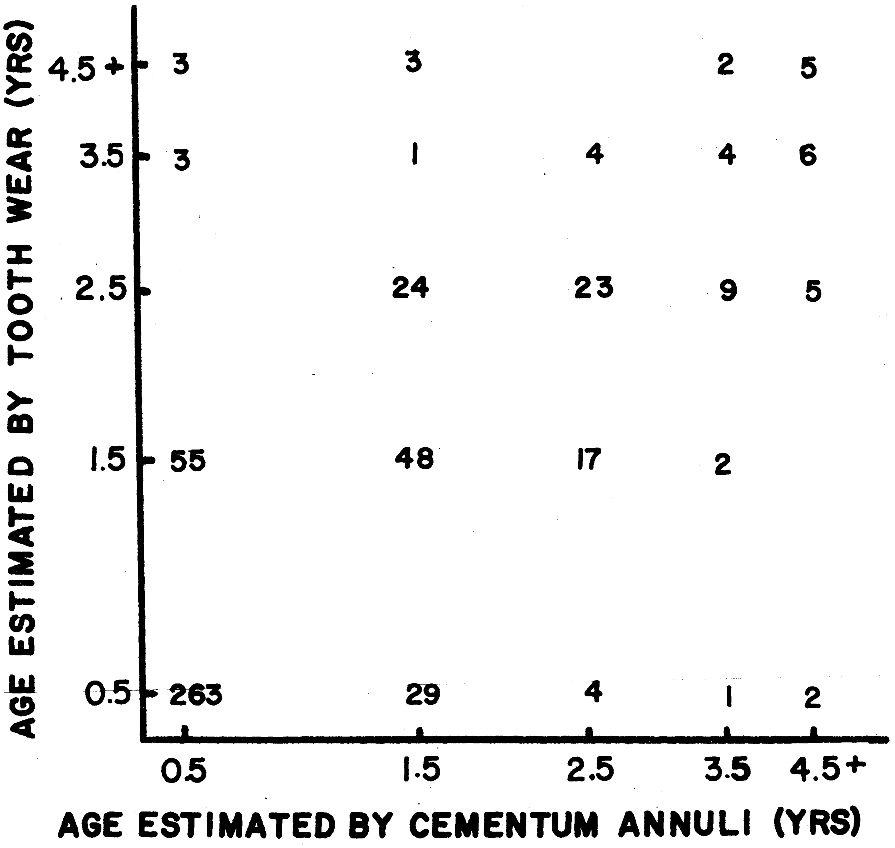
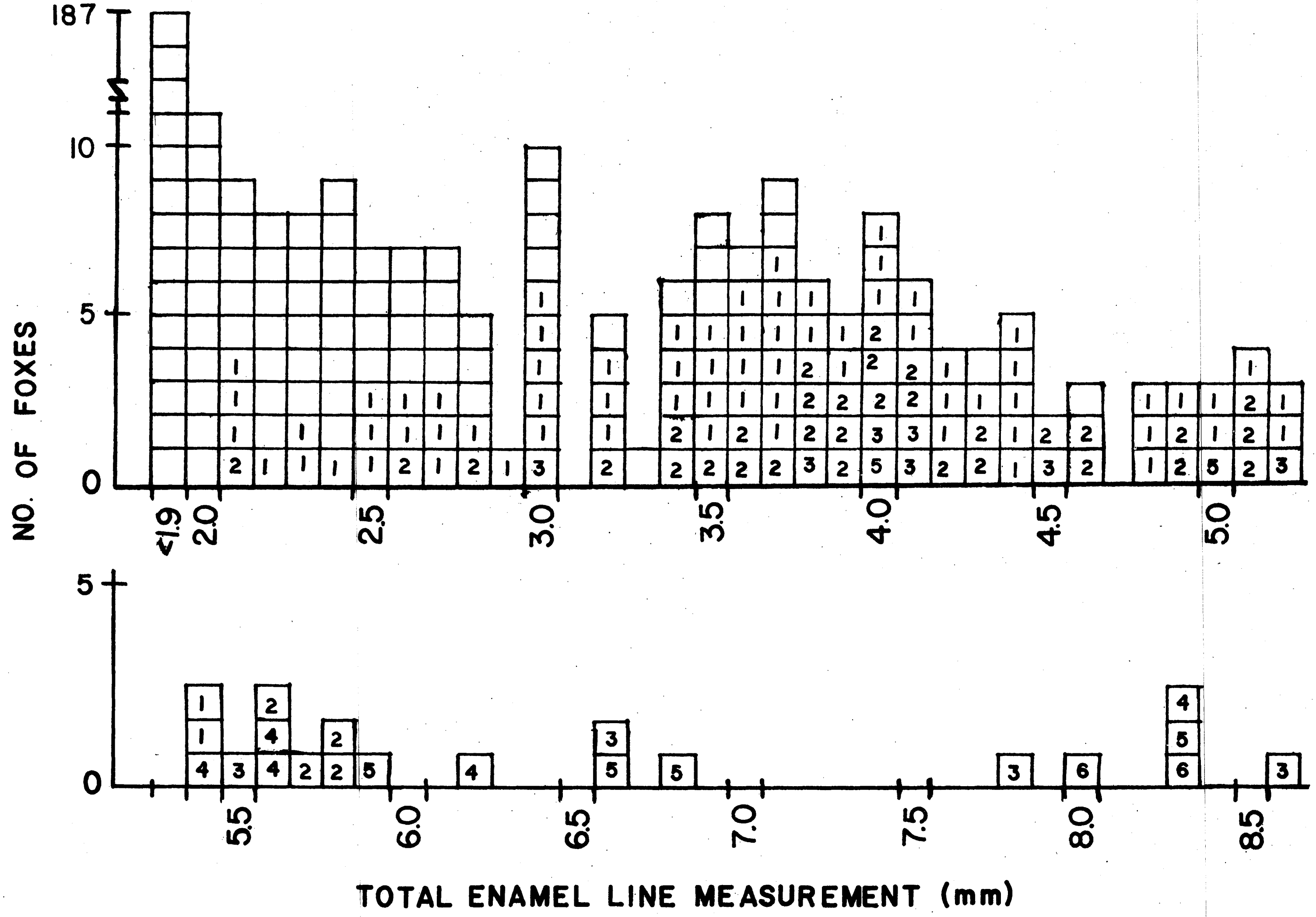

AGE ESTIMATED BY TOOTH WEAR (YRS)
4.5+
3.5
2.5
1.5
0.5
3
3
2
5
3
1
4
4
6
24
23
9
5
55
48
17
2
263
29
4
1
2
0.5
1.5
2.5
3.5
4.5+
AGE ESTIMATED BY CEMENTUM ANNULI (YRS)

Fig. 4. Distribution of the sum of the enamel height measurements (mm) from both upper canines of 387 gray foxes from southwestern Wisconsin. Numbers within boxes are years of age. Open boxes are juveniles.


NO. OF FOXES
187
10
5
0
<1.9
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5
0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
TOTAL ENAMEL LINE MEASUREMENT (mm)

Appendix B. First report of a samson gray fox.

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FIRST REPORT OF A SAMSON GRAY FOX

Key words: gray fox, samson, southwestern Wisconsin, *Urocyon cinereoargenteus*

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Although there have been numerous reports of samson red foxes (*Vulpes vulpes*) (Helminen 1961, Allen 1974) and other carnivores (Allen 1974), there have not been comparable reports for the gray fox (*Urocyon cinereoargenteus*). Failor (1977) stated that this condition occurred more often among red than gray foxes, but could not document an observation of a samson gray fox. No Wisconsin records of samson gray foxes are known.

In late November 1979 a complete samson gray fox was shot in Richland County, Wisconsin. Gross examination revealed a lack of guard hairs over the entire body, in contrast to a lack of guard hairs restricted to the tail and hind quarters which is characteristic of partial samson foxes (Allen 1974). External measurements were: head, 148 mm; tail, 320 mm; hind foot, 132 mm; total body length, 641 mm. Jackson (1961) gave the following approximate measurements for the gray fox in Wisconsin: tail, 310-390 mm; hind foot, 130-145 mm; total length, 950-1,040 mm. Gross body weight was not recorded, but the animal appeared to be in good overall condition when shot. Tooth wear patterns (Wood 1958) indicated that this male was <1 year old when killed.

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Jackson, H. H. T. 1961. Mammals of Wisconsin. Univ. Wisconsin Press, Madison. 504pp.

Wood, J. E. 1958. Age structure and productivity of a gray fox population. J. Mammal. 39:74-86.

Received ______________________.

Accepted ______________________.

Appendix C. Causes of death of gray foxes from southwestern Wisconsin, 1978-80.

Age (years)	Hunted		Trapped		Vehicle kill		Found dead		Unknown		Combined		
	M	F	M	F	M	F	M	F	M	F	M	F	COMB
0.5	50	56	108	119	17	11	1		27	31	203	217	420
1.5	21	15	24	30	4	4	1		9	10	59	59	118
2.5	10	9	15	14	2				5	3	32	26	58
3.5	6	2	2	4					2	2	10	10	20
4.5	2	2	4	1							6	3	9
5.5		1		5					1	1	1	7	8
6.5	1		1	1							2	1	3
Total	90	87	154	174	23	15	2		44	47	313	323	636
Adult	40	31	46	55	6	4	1		17	16	110	106	216

Appendix D. Causes of death of raccoons from southwestern Wisconsin, 1978-80.

Age (years)	Hunted		Trapped		Vehicle kill		Unknown		Combined		
	M	F	M	F	M	F	M	F	M	F	COMB
0.5	154	143	185	168	10	9	121	85	470	405	875
1.5	27	40	38	29	1		26	17	92	86	178
2.5	24	19	25	27	1		22	17	72	63	135
3.5	15	7	15	17			9	16	39	40	79
4.5	6	4	6	11		1	2	8	14	24	38
5.5	3	7	4	6			5	1	12	14	26
6.5	4	4	2	2			1	1	7	7	14
7.5	2	1	1	5				1	3	7	10
8.5		1		1				2		4	4
9.5		1		1						2	2
Total	235	227	276	267	12	10	186	148	709	652	1,361
Adult	81	84	91	99	2	1	65	63	239	247	486