ACTIVITY RHYTHMS AND DIET SELECTION OF RED FOXES, IN A MIXED FOREST IN ITASCA STATE PARK, MINNESOTA

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This is to certify that I have examined this bound copy of a master's thesis by

Mary Louise Batterson

and have found it is complete and satisfactory in all respects, and that any and all revisions required by the final examining committee have been made.

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Faculty Advisor

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22 July 94
Date

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and realize my dreams. Only true love would allow scat to be kept in the freezer and sample remains to be analyzed in the dining room.

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"I tread in the tracks of the fox which has gone before me by some hours, or which perhaps I have started, with such a tiptoe of expectation, as if I were on the trail of the spirit itself which resides in these woods, and expected soon to catch it in its lair."

Henry David Thoreau

Chapter 1

Activity Rhythms of Red Foxes in a Mixed Forest

INTRODUCTION

The red fox (*Vulpes vulpes*) has been studied from a variety of viewpoints over many decades (Cochran and Lord, 1963; Ables, 1969; Goszczynski, 1974; Insley, 1976; Sargeant, 1979; Broekhuizen et al., 1980; Tester, 1987; Jedrzejewski et al., 1989; Cavallini and Lovari, 1991; Meia and Weber, 1992). Red foxes are found in almost every habitat, including the tundra, boreal forests and prairies (Dekker, 1983; Brown and Triggs, 1989; Allen and Sargeant, 1993). Their habits, such as predation, parental interaction and breeding, diet, reproduction and dispersal have been given thorough examination (Storm et al., 1976). The actual activity, such as foraging, resting, or hunting, of foxes has been studied less extensively (Storm, 1965; Jensen, 1973; Amstrup and Beecham, 1976; Asa and Wallace, 1990), and there is minimal data on forest dwelling red foxes.

In conjunction with studying red foxes' nocturnal and crepuscular activity patterns, this study focuses on the activity rhythms of foxes within a protected habitat. Foxes that live in predominately forested areas may use their available area differently than foxes on farmsteads, open fields or prairies. Moreover, activity patterns of foxes located in a state park have not previously been examined. In a protected habitat, the researcher can determine more accurately how the red fox, a normally elusive and shy wild animal, uses its resources and goes about daily life. Protected from the stresses of being hunted and trapped, red foxes in a state park are naive to humans and easily used as study subjects.

The goal of this study was to determine the activity patterns of red foxes during the spring and summer pup rearing seasons in the protected environment of Itasca State Park, Minnesota. The hypothesis was that red foxes in a forested, protected environment exhibit increased activity during the hours between sunset and sunrise, and this activity would be confined to a crepuscular pattern.

Study Site: The study site consisted of the entire 130 km^2 of Itasca State Park, located in north central Minnesota (46° N, 95° W; elevation: 1445 feet). The area is a mix of coniferous and hardwood forests, wetlands, lakes and bogs and is at the juncture of extensive coniferous forests to the north, hardwood forests to the south and east, and prairies to the west. The climate is continental, with warm summers and cold winters. Hunting and trapping of wild animals, except white tailed deer (*Odecoleous virginianus*), are prohibited in the park. My study done in a protected environment provided different information than studies in areas completely inhabited by humans. A study by Servin et al. (1991) demonstrated that foxes in areas disturbed by humans exhibited primarily nocturnal activity, rather than crepuscular activity.

In northern latitudes, red foxes whelp in late February or early March, after approximately 52 days of gestation (Storm et al.,1976). The vixen is confined to the den until the pups are approximately 2 weeks of age, after which she continues to nurse, but after the two week confinement period, she becomes active outside the den (Storm, 1966). Both the vixen and dog fox hunt for food for the pups until the pups are approximately 12 weeks of age (Sargeant, 1978). Carnivores are among the few species in which the male contributes to the feeding of the young (Krebs and Davies, 1987). My study examined the activity of both the vixen and dog fox of two separate pairs during the period of pup rearing and through the summer until mid-August. An additional vixen was also tracked during this period.

Using radio telemetry proved an advantage for being able to follow the activity rhythms of elusive animals in a natural state without being intrusive (Cochran et al., 1965). Telemetry is a superior method of obtaining activity data which may not otherwise be readily accessible (Sargeant, 1979). Adams and Davis (1967) found that radio tracking provides the best means for determining the reasons behind an animal's movements. The technique of determining activity from variations in radio signals has been used in multiple studies (e.g., Lindzey and Meslow, 1977; Lancia et al., 1979). Tester (1978) and Garshelis et al. (1982) used radio signals to quantify animal activity through the use of motion sensitive switches.

This study is in partial fulfillment of the requirements for the Master of Science degree and was financed by the Big Game Club Fund through the Minnesota Foundation. Additional funds and equipment were furnished by the University of Minnesota Itasca Forestry and Biological Station, and equipment and technical expertise were provided by Advanced Telemetry Systems, Inc., Isanti, Minnesota. This study was performed under University of Minnesota Animal Care Committee Protocol number 9405005.

METHODS

Trapping: Foxes were trapped using padded leg-hold traps, size 1.5 (Woodstream Corporation of Lititiz, PA). Areas of fox activity were identified based on urine scent, tracks, scat and presence of kits. Pairs were determined by the presence of kits, heavy scenting by males, and characteristic barking within a specific territory. In each area where activity was found, three or four traps were set by a commercial trapper, using beaver meat as bait for females or commercial scent lures for males. Trap lines were checked every 12 hours.

Sedation: When a fox was captured it was restrained using mesh nets and injected intramuscularly with a solution of 0.5 mg/kg xylazine (Rumpun®) and 0.8 mg/kg ketamine (Ketaset®) (Kreeger et al., 1990.). The fox was sexed, weighed and measured. Overall general health was assessed, lactation was noted and teeth were checked for approximate age based on wear. Any minor wounds were cleansed, and an intramuscular injection of penicillin was administered. A radio collar with a unique frequency, weighing 64 grams, was affixed. The frequency of the radio collar was tested, and the fox was placed in a tarp covered box trap to recover. After 1.5 hours, the fox was released at the site of capture.

Remote data collection: Each pair of captured foxes was assigned to a remote receiver, programmed to the unique frequencies of the foxes' collars. Each receiver was connected to a data collection computer (DCC), and activities were logged continuously. The DCCs were downloaded into a personal computer every ten days. The activity data were sorted by frequency and checked for anomalies. Manual tracking and location of foxes with handheld receivers was performed every seven days as a back up to the automatic data collection system and to determine the foxes' approximate locations.

RESULTS

Five foxes were captured during 68 trap days. The foxes had been assigned numbers based on their radio collar frequencies. The cature date and specific characteristics of foxes captured are shown in Table 1.

Activity: Activity was monitored at a rate of 20 times per hour over a 24 hour period for a variable number of days during spring and summer 1995. Fox 814 was monitored around the clock for 57 consecutive days. This fox was active at least once per hour during 46 of the 57 days. Fox 694 was tracked for 55 days and was active at least once per hour for 49 days. Fox 734 was active at least once per hour for 65 of the 76 days she was tracked. Fox 774 was tracked for 107 days and showed activity at least once per hour during 102 days. Fox 754 was tracked for 57 days, during which he was active at least once per hour for 46 days. By combining data from all periods, percent activity may be calculated. I calculated the percent of days active, determining the exact activity periods for each fox. Figure 1 is a presentation of activity patterns for all five foxes from June 15, 1995 to July 14, 1995. The amount of time each fox was active and inactive was measured for each hour of each day. Figure 2 shows the activity rhythms of the four surviving foxes from July 15 to August 14, 1995.

Pup rearing activity: Activity patterns for the last 5 weeks of pup rearing by all three female foxes are shown in Figure 3. Figure 4 presents the activity pattern during 8 weeks of pup rearing by fox number 694. Her mate, fox 754, was not captured until June 17, 1995. Patterns for the period June 1 to July 14, 1995 for foxes 734 and 774 (Bear Paw pair) are shown in Figure 5, for approximately the last 8 weeks of pup rearing. The patterns of fox 694 and 754 (Sewage Lagoon pair) from June 15 to July 14, 1995 are shown in Figure 6. Activities of foxes 734 and 774 are shown in Figure 7 for the period June 15 to July 14, 1995. It can be seen that fox pairs exhibit high activity levels during the pup rearing period. More remarkable was the clear tendency of paired foxes to hunt and rest at approximately the same hours.

My calculations extended into mid-August. Patterns of activity for fox 754, a lone male, whose mate died on July 13, are shown in Figure 8, and Figure 9 demonstrates the activity levels of foxes 734 and 774 for the period of July 15 to August 14, 1995. Patterns of the lone female, number 814, from June 14 to July 15, 1995 are shown in Figure 10, and her patterns from July 15 to August 14, 1995 are found in Figure 11.

DISCUSSION

Radio collars: The use of tip switches in radio collars to vary the pulse rate is accomplished by use of a mercury switch which indicates changes in collar position. All of the radio collars used in this study were fitted with this type of switch. Garshelis et al. (1982) concluded in a study of black bears that tip switches provide more accurate information than interval switches when used to make continuous judgments of activity. He found that those who employ data collection computers, as I did, have greater reliability in interpreting that data if motion sensitive switches are used in the transmitters. Although radio telemetry can provide a wealth of information on the activity of a specific animal, the signals cannot be used to interpret specific behavior such as running, feeding or grooming (Tester, 1987).

Data collection: Three DCCs were placed in the field, one assigned to each of two fox pairs and one assigned to the lone female. Each DCC also monitored a "control" frequency not assigned to any collared animal. Interference in the radio signal may result from topography and dense tree stands. I experienced this problem with several foxes. The pair located in the Sewage Lagoon (foxes 694 and 754) were often out of range as a result of the topography of the Sewage Lagoon, which is at a higher elevation than other areas of the park(Wright, 1993; Megard et al.,1993). There were many apparent out of range fixes logged by fox number 814, which was located on the shore of Elk Lake. These fixes would be defined as a pulse rate of < 10.

To compensate for possible signal loss, actual activity is expressed as a percentage of time active, compared to time at rest (Maurel, 1980). Although all foxes showed activity synchronized with the day-night cycle, no two foxes exhibited identical activity (Fig. 1). I observed that in the hour prior to sunrise and the hour prior to sunset the animals were active, but at much reduced levels.

Tester (1971) states that animals may behave abnormally for at least two days after being radio collared. I found this to be true of the males in my study, each of which were out its normal range for two days. However, I found no such abnormal behavior in the three females that were collared. The females may have remained in their normal ranges because they were rearing pups.

Each DCC was downloaded every 10 days. Although there may not be an activity record for each fox during each day for the exact same time periods, there is adequate representation from each fox. I was unable to calculate the same time periods for both pairs, as fox number 694 was killed in what was considered a severe storm on July 13-14, 1995, of such an intensity that it would ordinarily occur only once in 100 years. Based on transmitter pulse rates which were abnormally high (> 80) over a period of four days, then several days of pulse rates at a typical resting rate of < 19, I was able to determine from this data that her date of death was July 13, 1995.

Mated pair patterns: It is evident from the activity patterns shown in Figure 5 that pairs exhibit an almost identical pattern of rest and activity during pup rearing. This activity level is greatly reduced after the pups are hunting adequately on their own (Fig. 9). As seen in Figure 3, fox number 814, the lone female, exhibited much less activity during the period she was raising pups than did fox number 694 and fox number 734. It is unknown whether fox number 814 had a mate and if so, whether the mate was doing most of the hunting to feed the pups. That possibility could explain her low levels of activity seen in Figures 10 and 11, respectively. No male was sighted in the area, and no capture was attempted after June 15, 1995, due to extremely high ambient temperatures, which would place the life of the fox at risk (Kreeger et al., 1989). This female's pups were trapped multiple times, and they appeared to be venturing farther from the den site (528 meters) at approximately 8 weeks of age, earlier than the pups of the Sewage Lagoon pair or the Bear Paw Point pair. Fox 814's pups were often sighted on the park road, 173 meters south of their den, when the pups of the other two pairs were not yet venturing more than 50 meters' distance from their respective dens.

Percent activity: A cumulative pattern of percent activity from June 14 to July 15 of the three female foxes during the last 5 weeks of pup rearing, from June 15 to July 14 (Figure 3) does not show a consistently high level of activity, nor does it show the females were active during the same time periods. Figure 4 shows the low level of activity demonstrated during 8 weeks of pup rearing by fox number 694. She did have a mate (fox number 754, captured on June 17), but he was captured after pup rearing was mostly complete, and his participation is unknown. It is evident that females demonstrate individualistic patterns of activity and rest during pup rearing. These patterns vary after pup rearing has ended, when the females demonstrate lower levels of activity. During the period of July 15 to August 14, 1995, the widowed male fox, number 754, exhibited the same high levels and patterns of activity (Fig. 6) as he did prior to the death of his mate (Fig. 8). Either he continued with the duties of pup rearing, or he was only tangentially involved from the start of pup rearing and the activity levels exhibited are his individual patterns, whether mated or not. The female's (number 694) death occurred at approximately the 12th week of pup rearing, which is considered the end of the period of intensive parental involvement (Sargeant, 1978)

In Tester (1978), activity periods were split into small time slices. In reviewing the data from this study and using time periods shorter than 30 days, no noticeable differences were found in overall activity levels. Hence, activity levels of foxes are presented here based on typical pup rearing time periods and time periods in which I had cumulative data for all foxes (except where noted). I used longer time periods to show the emerging patterns of activity between pairs. Male fox number 754 was captured late in the season and provided data for two months, but critical pup rearing data were not available. Female fox number 694 died in mid-July; consequently, pup rearing data were available, but pair data over longer periods were not available.

All five foxes show a predominantly crepuscular pattern of activity. They were active during the hours of darkness, with only a few bouts of activity during the daylight hours, but activity was mainly concentrated near the hours of sunset and sunrise (Figs. 5, 6, 7). Servin et al. (1991), studied foxes in a national park and determined that foxes were limited to nocturnal patterns because of human disturbance. In other studies, foxes exhibited higher nocturnal activity, tending toward crepuscularity as Ables's (1969) study demonstrated. Although most studies conclude that foxes are primarily nocturnal, with variability among seasons and among individuals (Storm, 1965; Ables, 1969). Many studies show several long periods of rest and long periods of activity within a 24 hour period, as found by Tester (1987). The foxes in this study varied markedly from those models. The activity of four of the five foxes was intense and nearly continuous from 7:00 p.m. to 5:00 a.m., with the highest activity near sunset and sunrise. Tester (1987) acknowledges that foxes in the wild show more variability in their activity periods in relation to sunrise and sunset than do captive foxes. He states, "[T]he remarkable ability of a wild animal to vary its activities increases its survival through these adaptive measures."

Other Observations: Twice as many fox pups were captured, inadvertently, as were adults. Pups were released immediately, but on several occasions adults were observed fleeing the immediate area where the pups were in traps. No aggression was attempted and no defense of the pups caught in traps was performed by the adult. The adult did position itself a short distance from the pups, out of sight, and barked consistently until the whining, noisy pups were released. This behavior by the adult seem to coincide with the age of the pup. Pups captured at age 3-4 weeks resulted in an adult being highly vocal, but pups captured at age 5 weeks and older did not result in adult fox vocalizations. I was interested in the lack of aggression toward me and the lack of defense of the pups by the adult foxes. In a study performed by Dekker (1983), he found foxes aggressively defending their territory containing pups from coyotes. He also observed an instance where a coyote rushed a group of fox pups. The vixen barked a warning from some distance, rather than confront the coyote. Preston (1975) found in his study of home range defense that the male carries the primary responsibility of defense. Males were highly aggressive and initiated contacts with intruders repeatedly, whereas females interacted only once then retreated and avoided further contact. If this behavior holds true in the wild I would have to assume the adult who did not confront me or defend the pups was a vixen. This behavior by the vixen also lends credence to the theory that an animal will defect in order to survive and continue to reproduce (Krebs and Davies, 1987). In human terms, the adult fox was willing to sacrifice the pups rather than risk its death and be unable to reproduce again.

In addition, there was a marked difference in the behavior of the fox pups toward me based on age. Pups captured at less than 5 weeks of age whined, were generally passive and easy to handle. Those older than 5 weeks were much more aggressive toward me, made biting attempts, performed open mouthed gaping, ear flattening, snorted, barked and yipped at my presence. Despite the age of the pup, they were calmed by placing gloved hands on them during trap removal. Pups that were held attempted to curl themselves into a ball, possibly to protect their stomach, the most vulnerable body part of a canine. Although no biting attempts were made during the time older pups were held they did flatten their ears, performed mouth gaping and would not make eye contact. Lack of eye contact is a sign of submission in canines.

Pups above the age of 6 weeks scent marked the areas where they were trapped, whereas those younger did not scent mark in response to being trapped. It is my opinion that the scent glands were not yet functioning in the younger pups. All pups were successfully removed from the traps without the use of sedative drugs.

CONCLUSION

Although extensive research has been performed on red foxes activities, only a few focus on forested areas. The use of radio telemetry allowed the investigation of activity rhythms of the red fox in the wild. Five foxes were captured, resulting in two mated pairs and a lone female.

Mated pairs showed an almost identical pattern of rest and activity during pup rearing. Patterns of mated pairs were consistently lower after pup rearing was complete. All five foxes show a predominately crepuscular pattern of activity in contrast to most studies, which found foxes to be nocturnal. Wild foxes demonstrate a wide variability in their activity patterns when compared to captive foxes.

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Figure 1. Activity for all foxes. June 14 - July 15, 1995

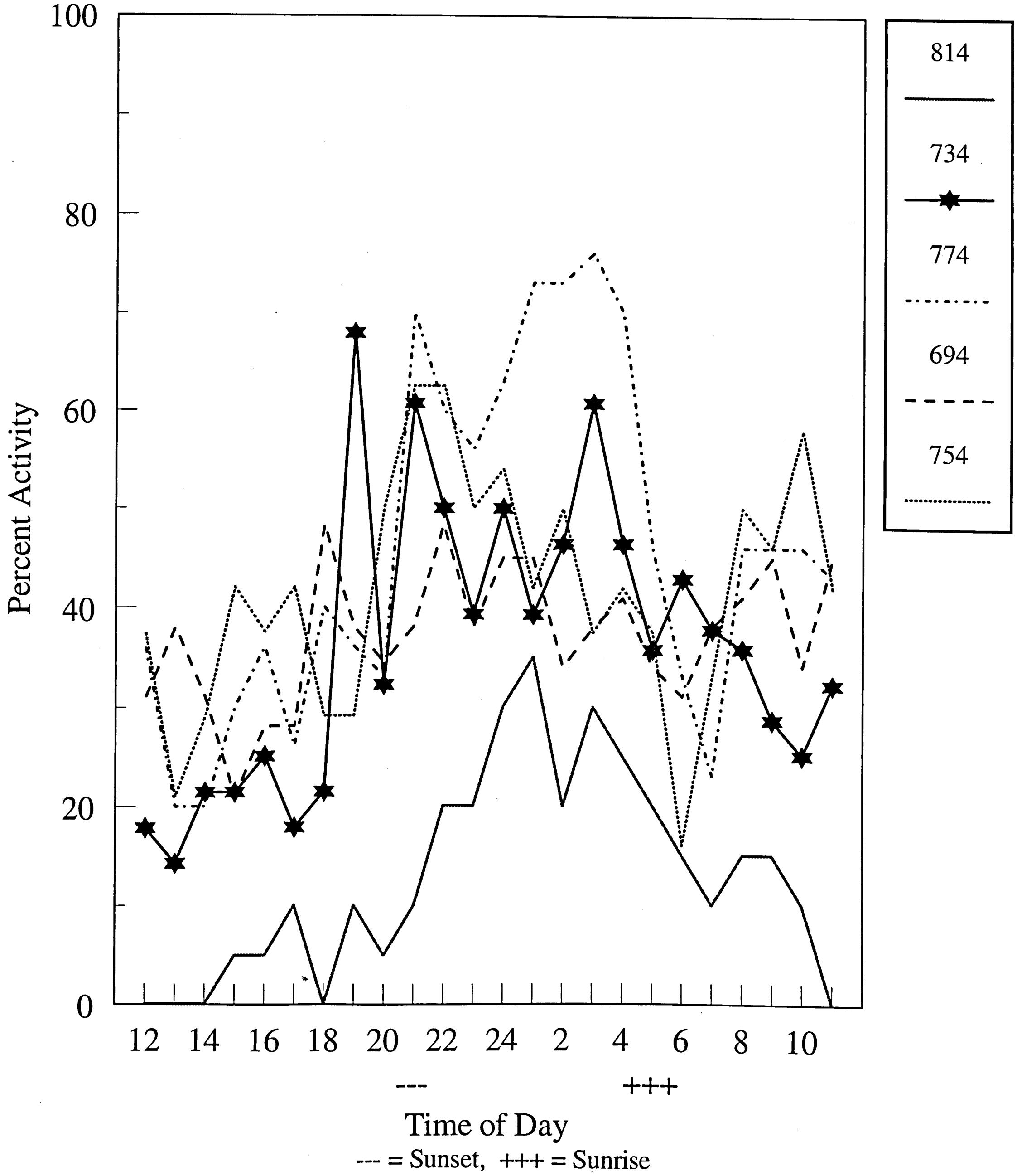


Figure 2. Activity for four foxes. July 15 - August 14, 1995

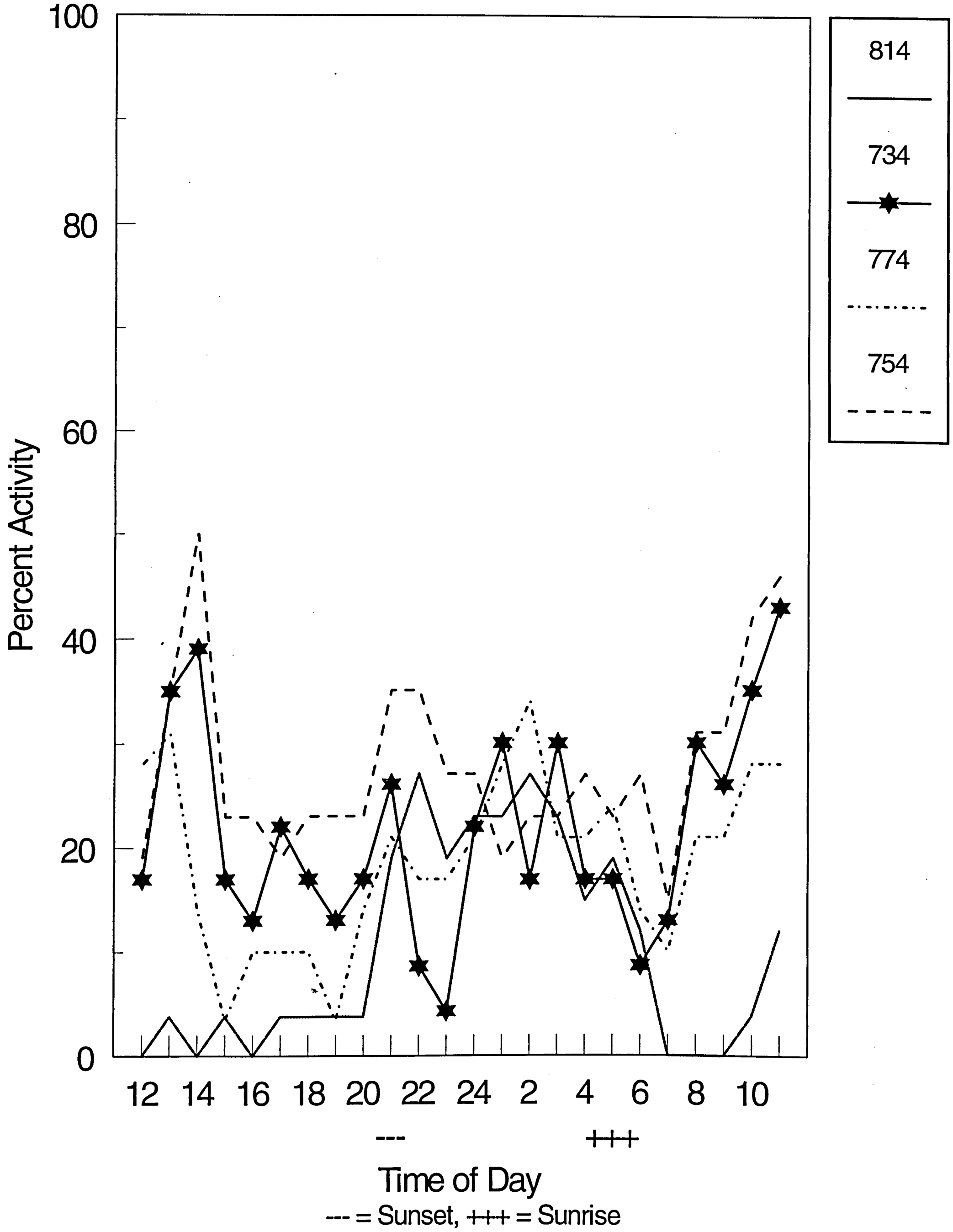


Figure 3. Activity Patterns for Female Foxes. June 14 - July 15, 1995 during last 5 weeks of Pup rearing.

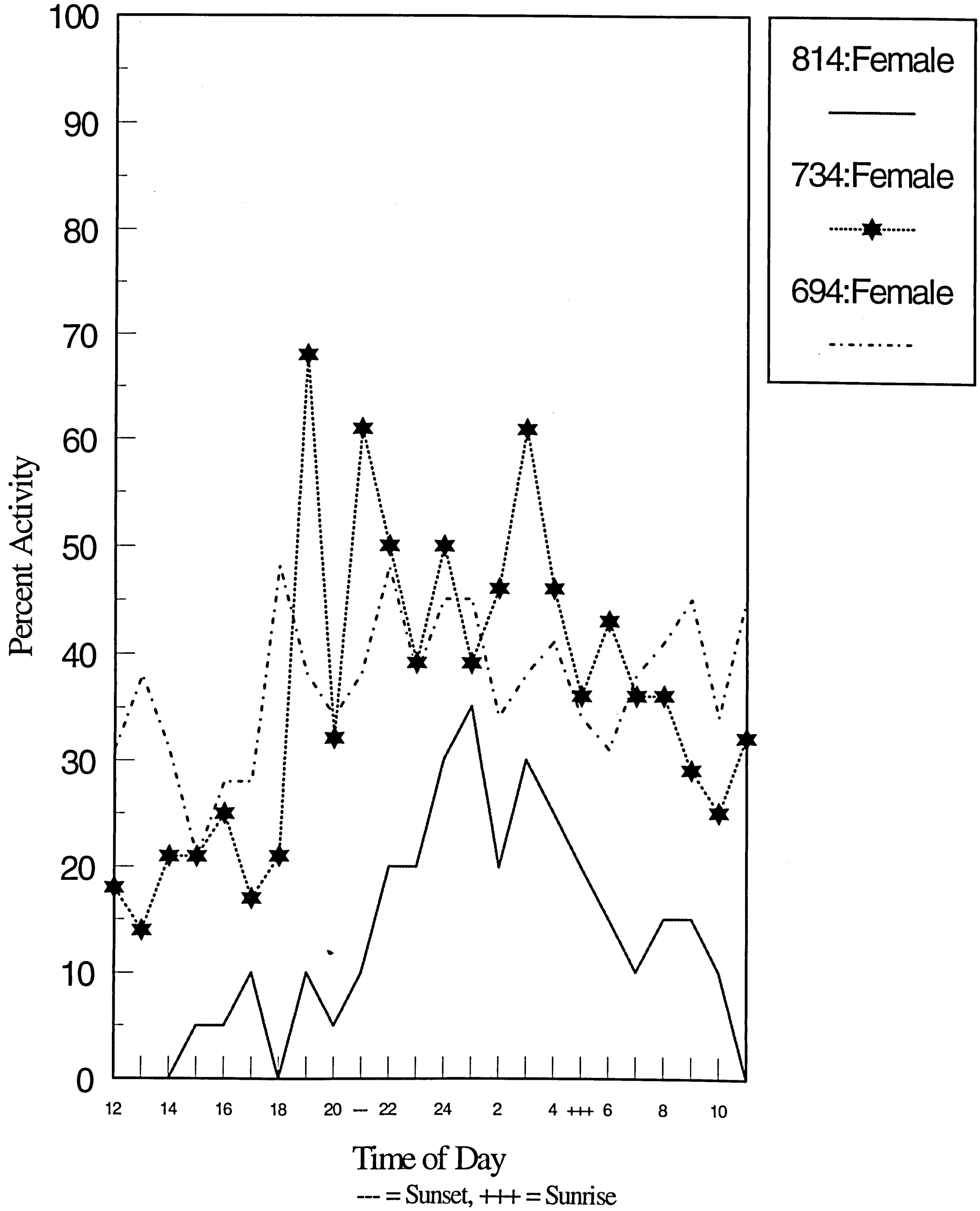


Figure 4. Activity Patterns for fox 694 during 8 weeks of pup rearing. May 20 - July 14, 1995

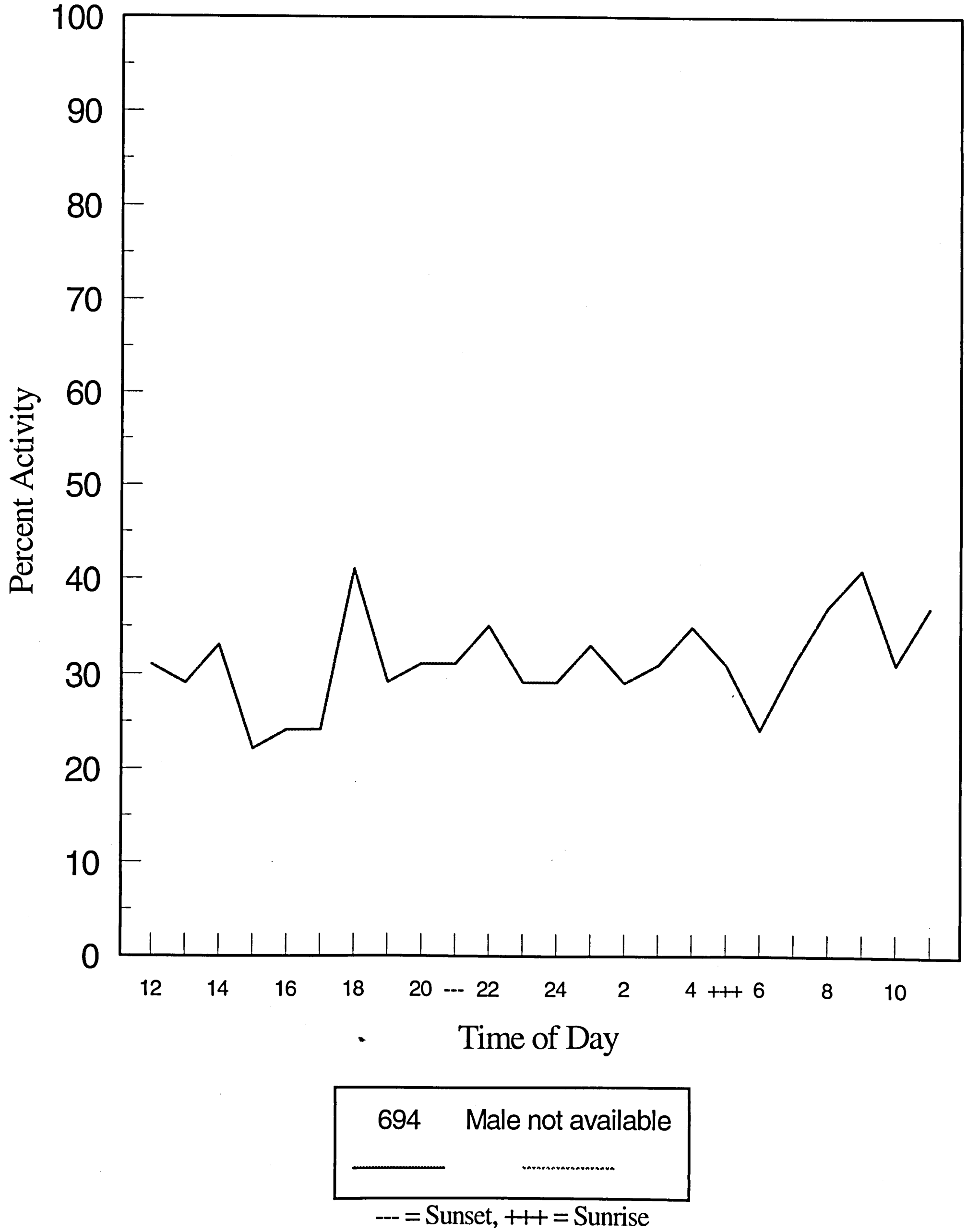


Figure 5. Activity Patterns for June 1 - July 14, 1995 Bear Paw Point Pair: last 8 weeks of pup rearing.

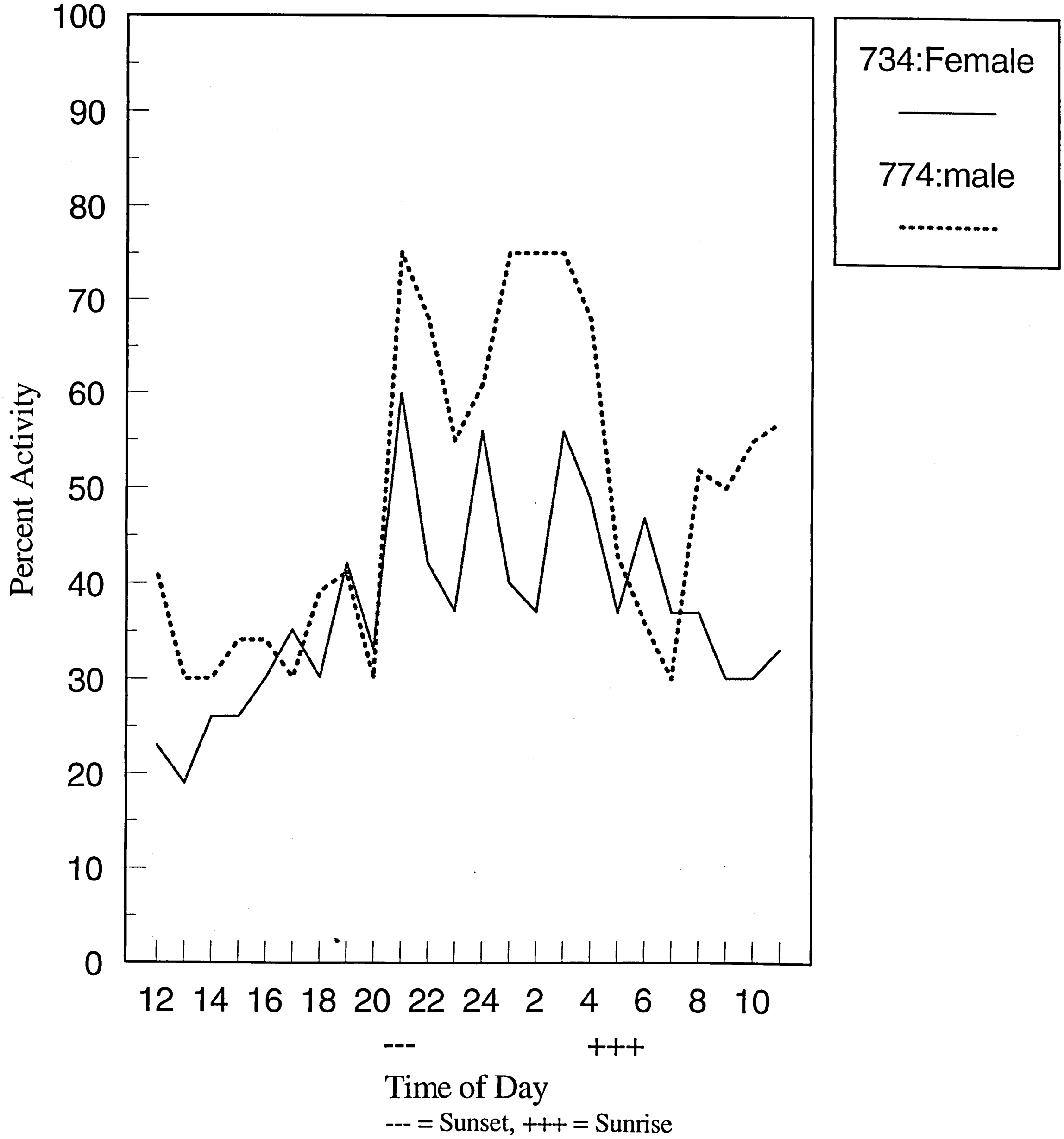


Figure 6. Activity Patterns for June 15 - July 14, 1995. Sewage Lagoon Pair

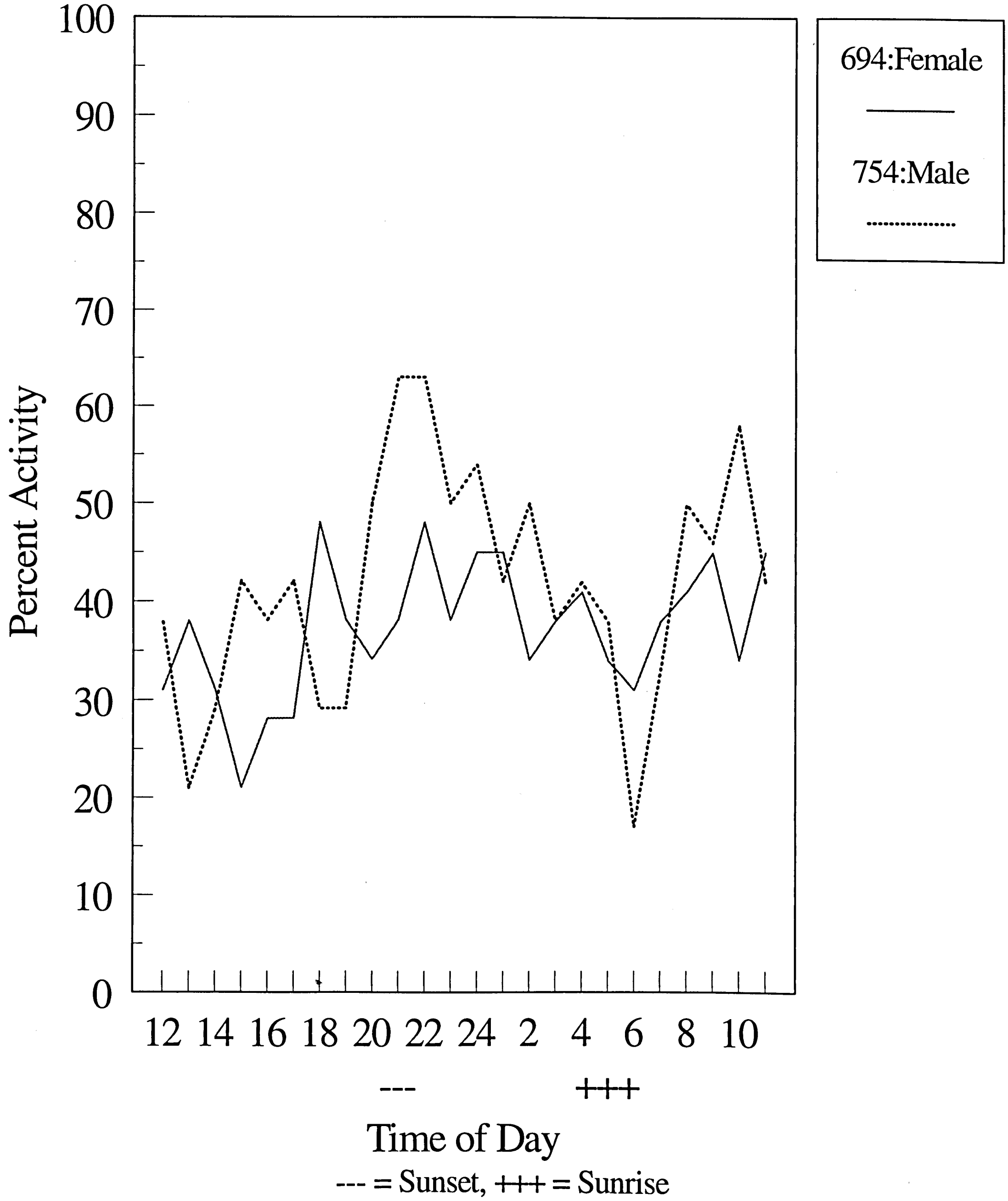
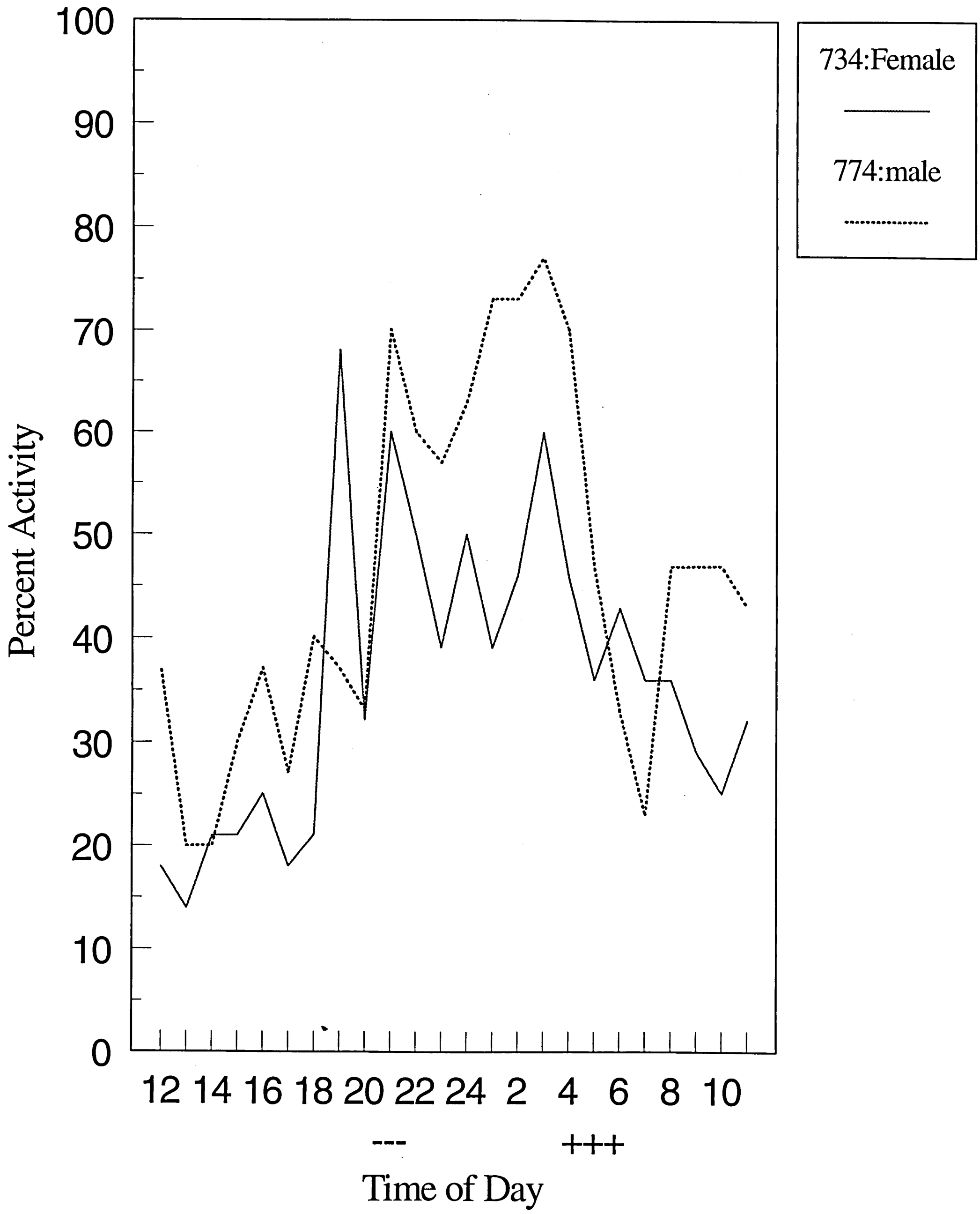


Figure 7. Activity Patterns for June 15 - July 14, 1995. Bear Paw Point Pair



--- = Sunset, +++ = Sunrise

Figure 8. Activity Patterns for July 15 - August 14, 1995. Sewage Lagoon Male

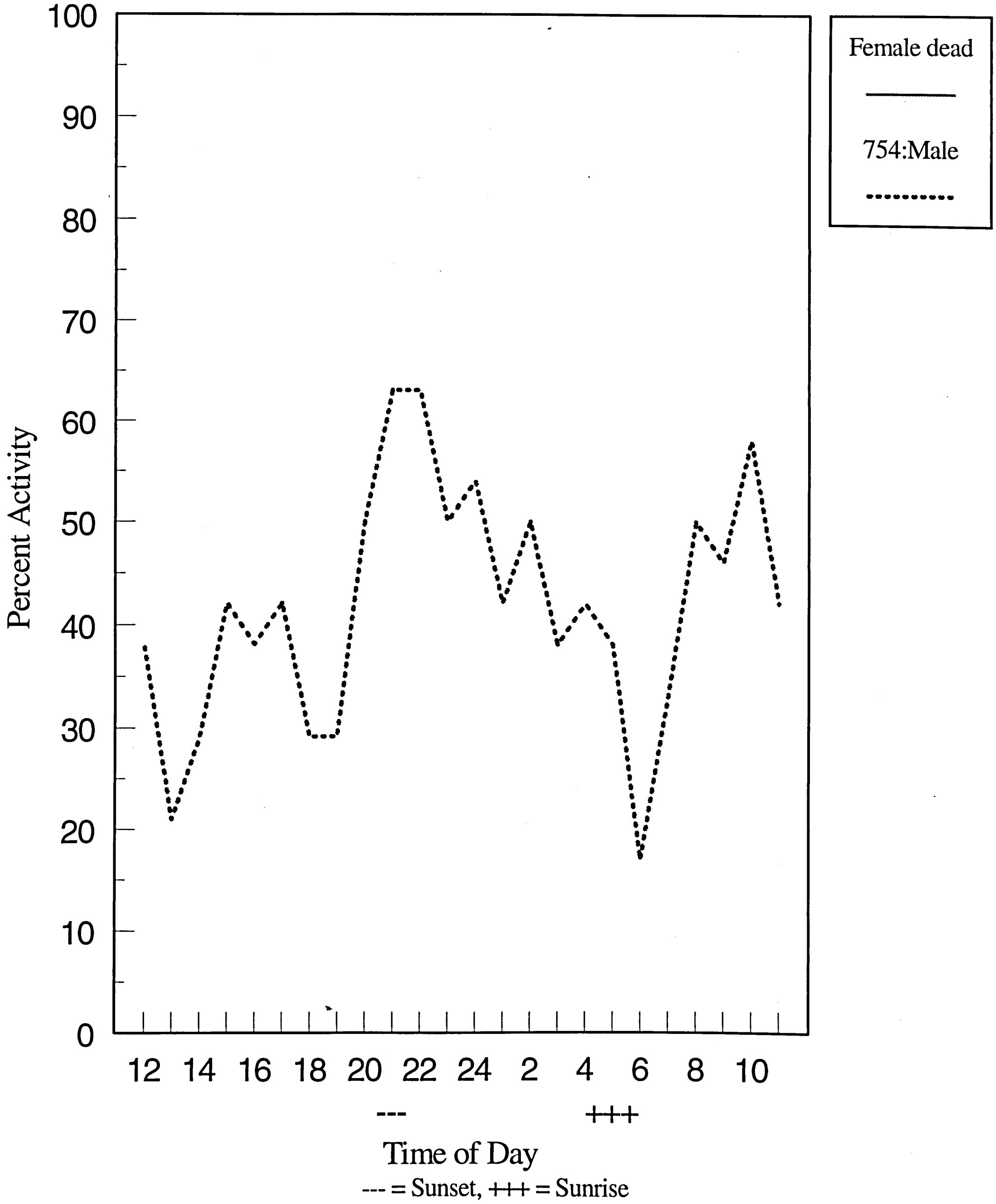


Figure 9. Activity patterns for July 15 - August 14, 1995. Bear Paw Point pair.

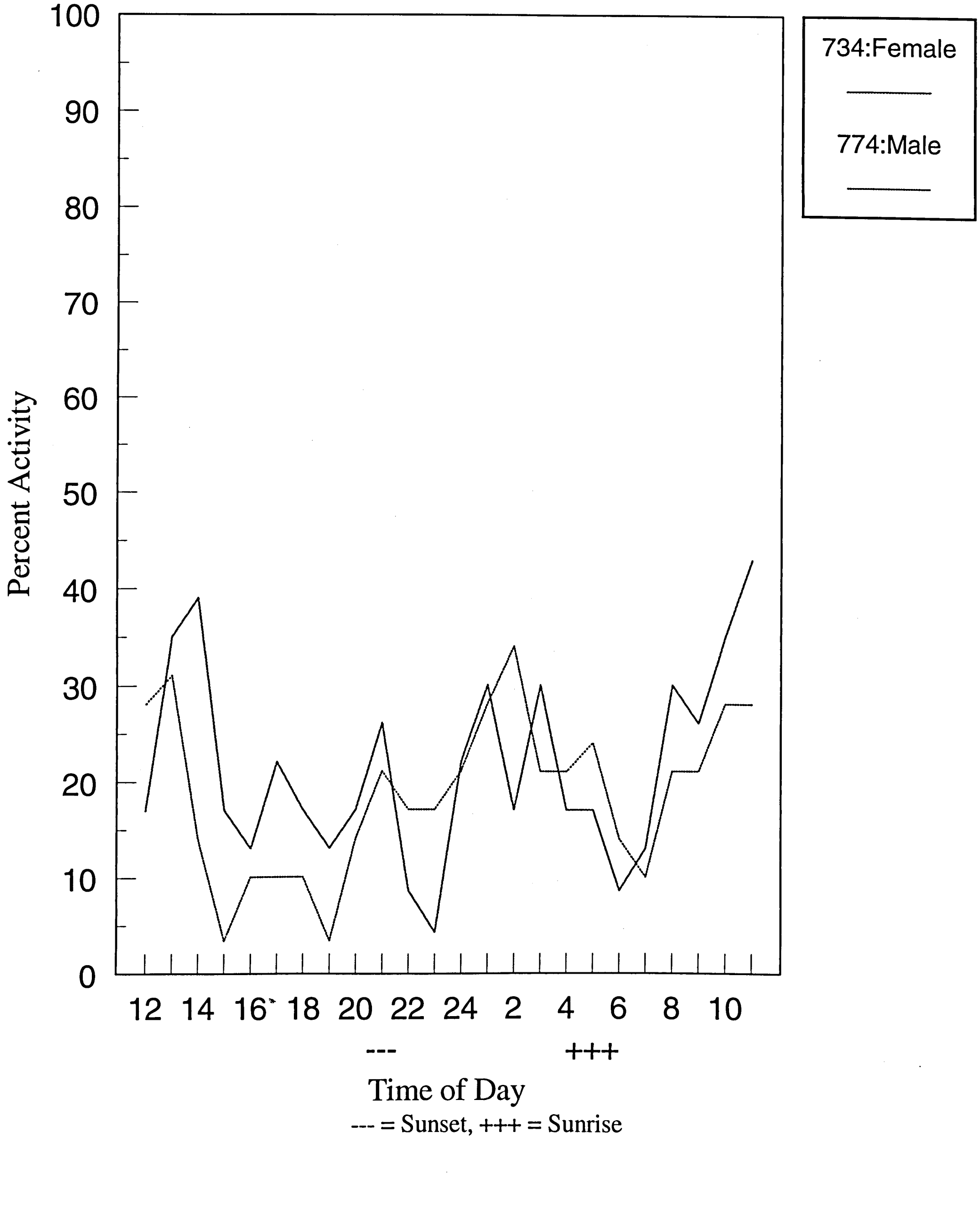


Figure 10. Activity patterns for fox 814.
June 14 - July 15, 1995

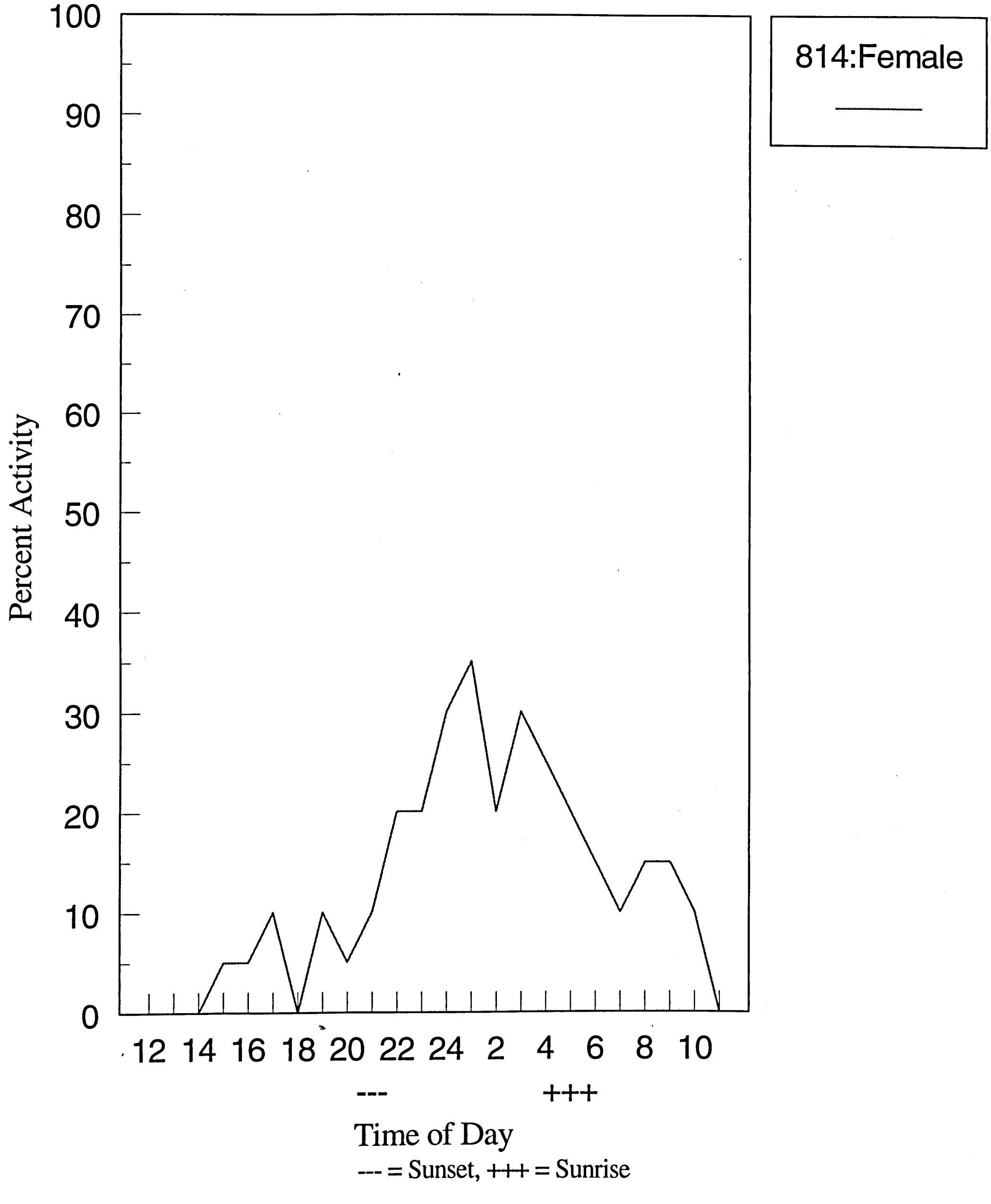


Figure 11. Activity patterns for fox 814. July 15 - August 14, 1995

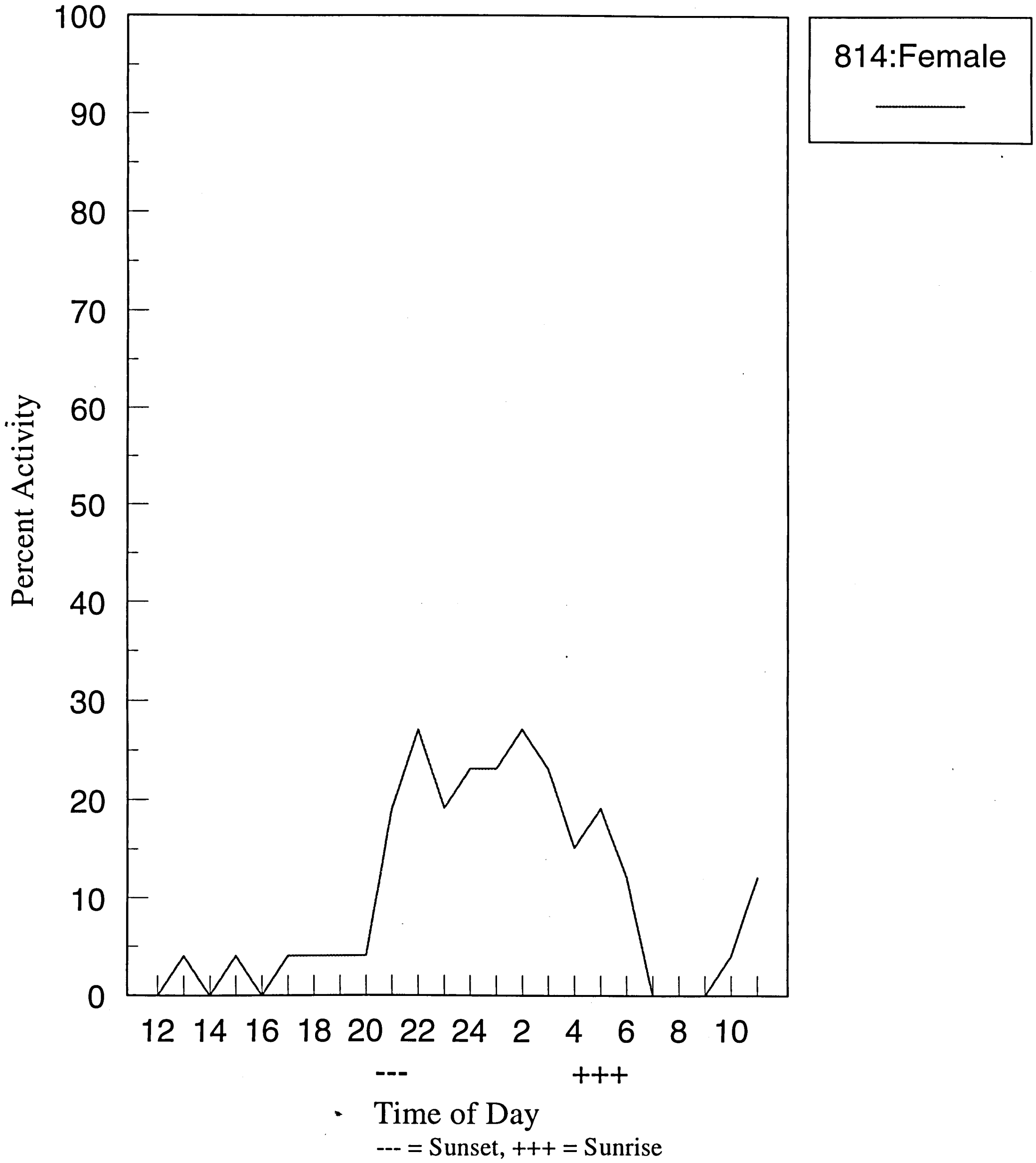


Table 1. Foxes captured in Itasca State Park 1995.

Date	Location	Sex	Fox No.	Temp (F)	Wgt (kg)	Approx Age	Lgth (cm)
4/28	Bear Paw Point	M	774	100.4	5	4.5	84
5/20	Sewage Lagoon	F	694	101.3	4.5	2.5	90
5/31	Bear Paw Point	F	734	103.2	3.6	2.5	87
6/15	Elk Lake	F	814	104.1	3.6	4.5	83
6/17	Sewage Lagoon	M	754	104.6	5.5	2.5	88

Chapter 2

Diet Selection of Red Foxes in North Central Minnesota

INTRODUCTION

Red foxes are opportunistic feeders. They rely on stealth and their keen senses of hearing and smell to detect prey, which is usually taken under cover of darkness. Their hunting areas are found in high grass, ferns and dense understory vegetation. They eat a varied diet, exhibiting clear seasonal patterns (Yonieda, 1982). Food habits are dependent on prey availability, with small mammals being the most stable food item category throughout the year (Errington, 1934). Jackson (1961) states that in his opinion, the red fox is more an economic asset than a liability, as it eats many mice, which are known to wreak havoc in agricultural areas.

The diet of the red fox has been previously investigated in various geographic areas and associated habitats such as open fields and agricultural areas (Errington, 1935; Hamilton et al., 1937; Cook and Hamilton, Jr,. 1944; Coman, 1973; Storm et al., 1976; Blanco, 1986; Fleskes and Klass, 1993). Heit (1944) investigated foxes found in marshes. Sargeant (1978) concentrated his efforts in prairie areas; and mixed types of forests were investigated by (Brummer et al., 1975; Green and Osborne, 1981; Lindström, 1983; Angelstam et al. 1984). Despite these studies, minimal research has been done on fox diets in forested areas (Errington, 1935; Hatfield 1939; Schueler, 1951; Johnson, 1969; Jensen and Sequeira, 1978; Jones and Theberge, 1983).

The goal of this study was to document seasonal dietary differences through scat analysis of the red fox in Itasca State Park, Minnesota. The study was conducted from July, 1994 to August, 1995 in Itasca State Park, Clearwater County, Minnesota. Itasca State Park includes the headwaters of the Mississippi River and is located at the juncture of three ecotones: the boreal forest to the north, prairie to the west and hardwood forests to the south and east. The ability to study red foxes in a forested environment, where no hunting or trapping pressures exist, provided a unique opportunity to determine their diet. The protected environment of the park provides access to foxes that are naive to these pressures, allowing them to be trapped easier. Because red foxes are nocturnal, it is difficult to observe their habits. Scat collection and analysis is an excellent method to investigate the dietary patterns of red foxes, and it is non-intrusive.

METHODS

Scat collection. Red fox scat was collected throughout the park on roads and trails and outside of active fox dens. Bicycle, hiking and cross country ski trails were rich with scat, as foxes defecate on the trail itself, rather than in the grassy adjacent areas. The entrances of active fox dens were searched and all food remains noted.

Scat Analysis. A sample was considered to be the entire mass defecated by the fox at one time. Each sample was placed in a plastic bag and dated. It was also noted if the scat was from a kit, based on a smaller diameter. Samples were frozen until processing was performed. Each scat was placed on a 0.05 mm mesh screen. The screen was passed through a high pressure stream of water to eliminate dirt and allow only solid items to be examined. Each sample was analyzed microscopically and cataloged based on the number of items found such as bones, teeth, insects, seeds and fruit. The food items were identified to species or to family using the collections maintained at the University of Minnesota's Itasca Forestry and Biological Station and the Bell Museum of Natural History at the University of Minnesota, Twin Cities. For small forms, such as mice, which foxes consume whole, fecal representations may approximate one individual.

Prey, such as mice, birds or insects, are taken based on availability, but hunting experience must be factored in when looking at the fox diet (Errington, 1934).

Remains of insects were determined based on elytra, antennae and legs, which allowed the remains to be identified to family. Frequency of occurrence was calculated on the 192 samples collected, with abundance defined as the highest percent of items found in a sample based on the overall number of samples. The chi-square test was used to detect differences in food items between seasons (Reynolds and Aebischer, 1991).

RESULTS

Individual red foxes displayed marked differences in food habits based on frequency of occurrence over the course of the study. Predominant food items found in fox scats were rodents, insects, fruit and seeds, along with unidentifiable rodent fragments, such as claws, bones and feet (Table 1).

The majority of bones found in the scats were severely damaged and unidentifiable to species, but most were determined to be rodents based on bone comparisons. In a total of 192 scats collected, 91 contained teeth which allowed identification of the food item to the species level (Table 2).

The meadow vole (*Microtus pennsylvanicus*) and red backed vole (*Clethrionomys gapperi*) were most abundant. Insectivores, such as shrews, were consumed, although several were also found killed but uneaten on known fox hunting trails. It appears the foxes found this group relatively unpalatable.

Food items were compared by season using a chi-square test. Fruit consisting of blueberries and raspberries demonstrated a clear seasonality ($X^2 = 26.37$, $P < 0.05$). Insects composed a stable portion of the diet and show a distinct change in seasons ($X^2 = 26.67$, $P < 0.05$), and invertebrates, such as crayfish and amphibians, were consumed on a seasonal basis ($X^2 = 12.02$, $P < 0.05$). There was no significant difference in the consumption of rodents among seasons, based on teeth and bone fragments found in scats ($X^2 = 0.732$, $P > 0.05$), and no seasonal differences were found in bird fragments or seeds ($X^2 = 2.941$, $P > 0.05$; $X^2 = 5.83$, $P > 0.05$, respectively). The seasonality of food items showing significance or no significance based on the chi-square test is shown in Figure 1.

DISCUSSION

The results show clear seasonal differences in several food categories, but a wider seasonal variability may have been determined had the number of scats collected been larger. Collection of scats was performed daily during the summer months from May until August, but only monthly during the remainder of the year. This may account for the comparatively low total number of scats collected and may influence the results.

Insects, invertebrates and fruit are clearly seasonal foods, based on their significant difference from other foods. I would have expected consumption of seeds from plants also to vary significantly between seasons, but it shows only minimal seasonality. The meadow vole was more abundant than other rodents when identified by teeth in scats. Four insectivores found in scats based on tooth identification are shown in Table 2. Short-tailed shrews (*Blarina brevicauda*) and water shrews (*Sorex palustris*) were found uneaten, possibly due to the presence of musk glands which emit an offensive odor. Scott (1943) found moles left uneaten on known fox trails, which he believed indicated that moles are distasteful to foxes.

Insects showed a clear difference in seasonal consumption as in Bowyer et al. (1983). Crickets and grasshoppers were heaviest in fall, as in Cook and Hamilton, Jr. (1944), and summer afforded dragon flies, beetles and ticks. Scott (1943) found plant material such as grasses, twigs, roots, stems and acorns in scats. I also found these items in >80 of scats, but it is unclear if foxes actually consume these items as a separate diet item or if they were consumed as part of other food items. Evidence of feathers and carcasses of mallard hens were found at active dens and in scats. Unlike Papageorgiou et al. (1988), amphibians were readily consumed by the foxes in my study during and after periods of heavy rain. Although the amphibians are easily digested and minimal evidence was found in scats, their consumption was visually observed on multiple occasions.

Using random sampling, percent occurrence in scats simply shows the prevalence of a particular food item and is not biased by food preferences of individual predators (Weaver and Hoffman, 1979). Rodent teeth appear most often in scats, as they may be the most difficult portion of an animal to digest. Limb bones were also quite prevalent, although most were in fragments. These food items are also difficult for the fox to digest. Prey items identified by species were found at den entrances and in the scat samples. Of those identified, the meadow vole and red-backed vole were most prevalent.

Diet studies using scat analysis have been performed successfully, but this method provides no actual volumes for each food type consumed. It does give excellent information on the foxes' range of dietary items and their seasonal variation (Brummer et al., 1975). Although analysis of this type can be questionable when easily digested foods are consumed, Scott (1943) ascertained this did not demonstrate a serious reduction in identifying food because of digestion. Certain foods are resistant to digestion or are retained in the stomach for variable periods of time, according to Errington (1934). Teeth and fur survive the digestive tract very well. Errington and Berry (1937) said, "Feces provide a more reliable quantitative index of fox food habits than do most items found at dens."

In the present study it was often difficult or impossible to attribute food items found in scats to a specific prey or vegetative food item. Bone fragments, which are difficult for foxes to digest, were nearly impossible to identify due to their fractured state. Sargeant (1978) found foxes inhabiting the North Dakota prairie do not digest feet, leg bones, the vertebral column, the pelvis and the frontal portion of skulls. My findings were similar. In some cases I was able to determine a prey item to species level based on feet with claws still attached, and the front portions of skulls often contained teeth, which are a major identifying feature.

Small Mammal Populations. The meadow vole was the most abundant rodent found in scats, concurring with Sargeant et al. (1986). They found these rodents to be one of the most predominant small mammals in fox diets. Yonieda (1983) found that foxes increase their consumption of rodents in spring and often in autumn. Cook and Hamilton, Jr. (1944) determined that foxes will consume meadow voles in spring and autumn, in addition to other foods.

The abundance of the microtine population and the ease of their capture make them an important item in red fox diets. Hamilton et al.,(1937) found the meadow vole was most abundant, which was also a major finding in my study. Korschgen (1959) determined that the feeding habits of foxes do not materially affect prey populations of either mammals or birds, but availability of prey is the key to the fox diet. Hamilton (1937) found that the cottontail rabbit (*Sylvilagus floridanus*) was favored as a staple in the fox diet during fall and winter. They also found shrews in the fox diet, and numerous studies discuss finding dead shrews, but left uneaten possibly due to the heavy odor.

Errington (1934) examined the contents of 52 fox stomachs, which showed an abundance of meadow jumping mouse (*Zapus hudsonius*) in the winter diet of red foxes. Deer mice (*Peromyscus maniculatus*) were found in 55 of 113 fox dens in Errington's study, and in 1,175 fecal samples examined during the spring and early summer, he found meadow mice 515 times and deer mice 104 times, respectively.

In a study by Hatfield (1939), mice were found in 21 of the 29 fox stomachs examined. Rodents and lagomorphs formed 69.2 percent of the bulk of the red fox diet. In 400 scats from all periods of the year analyzed by Schueler (1951) in a forested environment, and correlated with abundance and availability of foods, insectivores were high in May through July, rodent remains were highest in August, and hares and rabbits most abundant overall. Red squirrel (*Tamiasciurus hudsonicus*), chipmunk (*Tamias straitus*) and snowshoe hare (*Lepus americanus*) were regularly found. The scats he examined showed a high number of insectivores, despite the common belief that their taste is unpleasant to the fox.

Research in Edinburgh, Scotland by Lockie (1959) shows shrews being offered, but not eaten. In foxes fed red-backed voles, teeth were found in scats. Lockie also determined that foxes eat about 1 pound of food per day. In Korschgen's (1959) 7 year study, cottontail rabbits were found to be the primary food of the red fox. Small rodents, mostly meadow voles, deer mice and the house mouse (*Mus musculus*) occurred in 51.4 percent of the stomachs examined. Birds comprised 14.7 percent of the diet; 7.7 percent were songbirds. Korschgen's statistical analysis showed a slightly significant relationship between rabbit populations and foxes' consumption of rabbits. However, rodents are a staple dietary item of the red fox throughout the year. In foxes' summer diets, Korschgen (1959) found insects in 69 percent, and mice and rats in 35 percent, of the fox stomachs analyzed.

In a three year study performed in rough terrain, sandy soil and a primarily agricultural community, Scott (1943) found mammal foods to be lower in summer and fall than in other parts of the year. Meadow voles and meadow mice were preferred, but insectivores were uneaten. The meadow vole appears to be highly vulnerable to foxes, as it is frequently found in scat samples. Scott's fecal analysis showed insects comprising a substantial proportion of the warm weather diet. He also found that carrion was rejected by foxes if it was severely decayed.

Cook and Hamilton (1944) determined that brush and dense grass are excellent habitats for fox foraging. They examined 537 scats over six years gathered from roads, trails and large rocks. In their findings, cottontail rabbits comprised 29 percent, meadow mice 17 percent, grasshoppers 10 percent and one occurrence of a star-nosed mole (*Condylura cristata*). The red squirrel population in their study area was thin, in contrast to the high populations found in Itasca State Park. The park's high population may be due to its heavy stands of conifers producing good cone crops, a staple in the squirrel diet. Errington (1934) found small mammals taken by foxes prefer extensive concealing vegetative habitats. Deer mice are found in most cover types, as woodland habitat affords protection, snags and downed logs. The red-backed vole, which lives in burrows, is abundant in stands of conifers and mixed timber. Meadow voles prefer wet, tall meadows and fields of tall heavy grass. This habitat preference makes them particularly vulnerable to the red fox, as foxes hunt in meadows and tall grass. Cottontail rabbits are found in woodland openings and brush, areas that are typical hunting grounds for red foxes.

In the boreal forest comprised of white spruce, trembling aspen and balsam popular, Jones and Theberge (1983) determined that the snowshoe hare was a major part of the diet of foxes using this habitat type.

In a survey to determine the presence of certain mammals in Itasca State Park, Sargeant and Marshall (1959) determined that shrews are semiaquatic and that star-nosed moles inhabit shallow burrows just beneath the soil surface in damp areas. This species is commonly found on the edges of swamps and marshes. At the time of their study, the cottontail rabbit was considered scarce within Itasca, but my study revealed cottontail rabbit remains in a known fox hunting area, and several live cottontail rabbits were observed. In their study, tree squirrels were the most abundant of the sciurids, and the park is rich with conifers, which is their preferred habitat. In the scat analysis performed for this study red squirrel remains were evident. This small squirrel may present little resistance to predation by red foxes. Deer mice were abundant at the time of Sargeant and Marshall's (1959) study and are still a part of the Itasca red fox diet based on my findings. These mice are found in upland deciduous forests having a dense understory. Red-backed voles, prevalent in the fecal remains I examined, inhabit damp forested areas with heavy ground cover, many logs and brush. They can be found near bogs, in meadows and in fields, presenting optimal prey for foxes who also hunt in these habitats. The 1959 study found that the red fox was the most common and numerous of the Canids in the Park.

A study on snowshoe hares by Pietz and Tester (1983), in an area adjacent to Itasca State Park, showed hares most frequently are found in four habitats: jack pine, jack pine-alder edge, alder fen and black spruce bog, although hares avoided jack pine stands in upland habitat. At night, hares use jack pine, as these stands provide good quality browse, but poor cover. This use of cover poor areas at night makes hares particularly vulnerable to nocturnal hunting foxes. Hare tracks were found frequently in jack pine-alder edge habitats and foxes make excellent use of edge habitat when hunting. Few hare tracks were found in open habitats, where hares would be most susceptible to predation by red foxes. Pietz and Tester (1983) found a correlation between tall shrub cover and the density of snowshoe hare pellets, which may suggest that ground vegetation is primary hare habitat, irrespective of canopy type. By using dense shrub covered areas, hares may avoid their chief predator, the fox.

Summer diets of red foxes as discussed in Jackson (1961) suggests that mammals are the dominant food of red foxes, with cottontail most important, comprising as much as 60 percent of the fox diet in Wisconsin. Meadow voles are sometimes found to constitute half of the summer and fall diet. Again, there is a controversy concerning red foxes not relishing shrews, but Jackson notes that foxes often will not eat shrews after killing them.

Research performed by Ozoga et al. (1982) in the Cusino deer enclosure on the Upper Peninsula of Michigan showed that in 367 scats analyzed, snowshoe hare was the predominant prey of foxes in early May, and during mid-May and June insects became more numerous in the fox diet. By July and August, fruits predominated. My results are very similar, including the finding that mice and meadow voles are prevalent in scats throughout the summer.

To examine populations of the meadow jumping mouse, Tester et al. (1993) researched an area along the Mississippi River in Itasca State Park. They found that this species, a prey item of the red fox, selected habitats with dense grass and sedge cover near water. In the foxes' favor is the fact that this mouse used areas without tree or shrub canopy. Foxes have been observed in Itasca denning in close proximity to water, which (Tester et al., 1993), may also be a prime factor in meadow jumping mice's selection of habitat.

Avian populations.. A bird census performed by Kendeigh (1956) in Itasca State Park, specifically on the La Salle trail, which is comprised of red pine, white pine and thick understory, provides a detailed listing of birds and waterfowl found in this area of the park. During 1994 and 1995, the La Salle Trail was a major hunting and denning area for several red fox families. Kendeigh performed seven complete counts during the summer of 1955, and most of the birds were found from mid-June to mid-July. The results of my scat analysis show mallard ducks and grouse, so it appears that the foxes inhabiting the La Salle Trail and Sewage Lagoon area adjacent to the La Salle Trail are utilizing the waterfowl found there. Mallard hen, blue-winged teal and grouse carcasses, some half consumed, were found outside the fox den located adjacent to the Sewage Lagoon at least 23 times.

In a study performed by Sargeant, et al. (1984) in North Dakota, ducks were found at 1837 fox dens, of which 96.8 percent were dabbling ducks, mallards, pintails and blue-winged teal. Adult ducks made up 24 percent of 5402 individual food items found at dens in their study area. They found that foxes totally consume small prey, but leave remains from ducks and other larger prey. Their study concluded, as my evidence shows, that ducks are a relatively small part of the total fox diet.

Sargeant's (1978) study demonstrated fox kits may begin eating prey items brought to the den by their fourth week after birth. This time period coincides with the eruption of the kits' teeth. Annual rates of predation of red foxes on mallards in the Prairie Pothole region of North Dakota averaged 5.1 and 18.1 percent of the drake and hen population, respectively, over an 11 year study done by Johnson and Sargeant (1977). Predation by foxes appeared to affect the mallards, but mallards seem to contribute only minimally to the diet of the prairie red fox.

In my study a litter of six fox pups were being raised adjacent to the park's Sewage Lagoon. This area is a rich breeding habitat for mallards and pintails. The vixen was trapped and radio collared within the lagoon enclosure. Based on the number of mallard hen carcasses found outside her den, it appears she preferred hunting in this lagoon area where ducks and pintails nest in the tall grass and provide easy prey. Fox pups at this den were observed eating and playing with the mallard carcasses. Mallards nest early in the season, hence the opportunity is presented during pup rearing to exploit these birds for food. Sargeant et al. (1984) determined that foxes prey selectively on dabbling duck hens, and my study also showed predation on these species.

Fruits. Fruits such as blueberries and raspberries are typical supplemental foods in the fox summer diet. Fruits are of higher importance to the fox in summer based on their availability (Scott, 1943). In Schueler's study (1951) fruit was high in July, with peak consumption in August, consisting of mostly raspberries and blueberries. My results show the same fruits in scats during the late summer.

Seeds. Wild sarsaparilla (*Aralia nudicaulis*) is a perennial forest herb which is abundant under hardwood and mixed timber. Hamilton's (1937) research showed the summer fox diet containing both seeds and fruit, such as seeds of wild sarsaparilla and blueberries. I found an overwhelming number of seeds identified as wild sarsaparilla in summer scats.

Insects. Insects comprise a large percentage of occurrence in the fox diet. However, they constitute a very small actual dietary food source according to Burrows (1968). Insects such as dragonflies, beetles and ticks were well represented in my study. I believe the ticks were more a consequence of grooming, than a deliberate food item.

Amphibians. Although amphibians are difficult to identify in scats, foxes were observed during the summer of 1994 and 1995 on park roads eating frogs as quickly as they could be caught during periods of heavy rain and shortly thereafter.

Other Observations. Found outside an active den used by two radio collared foxes were mallard hens, a porcupine (*Erethizon dorsatum*), raccoon (*Procyon lotor*), walleye (*Stizostedion vitreum*), muskrat (*Ondatra *zibethica*) and portions of deer carcasses (*Odocoileus virginianus*). Multiple deer mouse skins, with internal organs eaten, were found on several trails. In addition, partially eaten birds, raccoons, deer mice, cottontail rabbit and grouse were found on known fox hunting trails.

Potential Questions for Future Research. Foxes use scat and urine to mark their territory boundaries. It is unknown if the scat collected in this study had any impact on territorial disputes, but it was observed that several known fox territories contained high amounts of feces. Scat in these areas could be collected as often as twice daily.

This leads to the following questions. Are foxes remarking their territory after finding their "markers" missing? Does scat collection cause confusion in territorial boundaries? Does scat collection lead to territorial disputes? Further research is needed to accurately answer these questions and determine what impact scat collection may have on red foxes.

CONCLUSION

Although I was expecting to find that red foxes inhabiting a forested environment would have food habits differing from foxes residing on prairies or agricultural lands, this was not the case. The foxes residing in Itasca State Park consume practically identical food items to foxes living on the prairie (Sargeant et al., 1986) and with those living on agricultural lands (Errington 1935). Foxes living in proximity to humans, be it the park, prairie or agricultural lands tend to scavenge from humans. Multiple scats contained aluminum foil and plastic wrap which are not normally food items consumed by foxes.

Red foxes living in close proximity to humans develop a keen wariness if they have been subjected to trapping pressures. Many farmers consider the red fox to be a pest rather than a partner in ridding the farm area of rodents. In contrast, my study within Itasca State Park, where no trapping is permitted, found foxes were naive of these pressures and were easily trapped, with several foxes being trapped twice and one being trapped three times. These same foxes are easily captured by local land owners after venturing outside of the park.

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Table 1. Frequency of occurrence of seasonal fox food items.

Food Item	Summer *n = 26*	Fall *n=14*	Winter *n=32*	Spring *n=79*	Summer *n=41*
Rodent teeth	0.44	0.50	0.44	0.44	0.51
Insects	0.60	0.71	0.22	0.35	0.70
Avian	0	0	0.03	0.05	0.07
Invertebrates	0.04	0	0.03	0	0.12
Rodent fragments	0.80	0.93	0.63	0.81	0.68
Fruit	0.24	0.07	0.03	0	0.04
Seeds	0.28	0.07	0.25	0.13	0.15

Table 2. Food items identified by analysis of teeth in fox scats.

Food Item	*Number*
Rodents	
Mus musculus	2
Clethrionomys gapperi	20
Microtus pennsylvanicus	40
Peromyscus maniculatus	3
Tamiasciurus hudsonicus	3
Synaptomys cooperi	2
Napaeozapus insignis	3
Insectivores	
Condylura cristata	2
Sorex palustris	1
Blarina brevicauda	1

Figure 1. Chi-Square seasonal comparison of food items