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RH: Breeding biology of a captive swift fox population

**CAPTIVE BREEDING OF THE SWIFT FOX AT THE COCHRANE
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Abstract: An analysis of the swift fox (*Vulpes velox*) captive-breeding program at Cochrane Ecological Institute, Cochrane, AB, Canada from 1972 to 1997 is presented. During that period, captive breeding of swift fox provided 841 animals to the Canadian swift fox reintroduction program in southern Alberta and Saskatchewan (Smeeton and Weagle, 2000). The founder population consisted of 34 individuals, the majority of which came from wild populations in the United States. The 272 litters produced averaged 3.6 \pm 0.45 live kits per litter with a range of 1 – 7 kits. Captive-born yearling females had a lower fecundity than females > 1 year old [$\chi^2 = 0.05$], with the highest fecundity in their fifth year. Captive-born yearling males also had a lower fecundity than other ages [$P < 0.95$] with highest fecundity being found in years 9 and 10 [$\chi^2 = 0.05$]. In wild-born males, fecundity was lower than all age groups except yearlings [$\chi^2 = 0.05$]. The maximum number of live kits produced by a female was 33 over 8 years and 46 by a male over 14 years. Most litters (71%) were born between 16 April and 10 May with some whelping as late as 26 June. Nineteen percent of yearling females and 18% of yearling males produced litters when paired with an older animal, whereas 11% of pairs with both male and female yearlings produced litters. Females did not produce litters after 8 years of age, but males continued to produce litters to age 14.

Key words: breeding behavior, captive breeding, reintroduction, swift fox, *Vulpes velox*

Captive breeding of the swift fox (*Vulpes velox*) began in Canada in 1972 at the Wildlife Reserve of Western Canada (now the Cochrane Ecological Institute [CEI]), 6 years before the species was declared extirpated in Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 1978). The specific goal of CEI is to produce

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swift foxes of maximum genetic heterozygosity for reintroduction into protected areas of their historic range.

Although CEI has bred swift foxes in captivity for over 25 years, little has been published on the methods or results of the program. Schroeder (1987) summarized some of the findings to date and determined the gestation period to be 51-52 days; his observations were conducted at CEI and the Calgary Zoo. Weagle and Smeeton (1995) summarized behavioral characteristics of the foxes at CEI and Teeling (1996) reported detailed observations of captive breeding behavior at CEI. Bremner (1997) developed environmental enhancement procedures for captive breeding enclosures at CEI.

Our objective is to describe the breeding biology of swift foxes in a captive breeding facility. Data were taken from the CEI studbook for swift foxes and from daily observations of the foxes. The protocols for the feeding, housing, and health care that were developed over the 25-year captive breeding program are presented in Smeeton *et al* (In prep.).

Methods

Facilities: CEI is situated in the foothills of the Rocky Mountains and within the historic range of the swift fox. The 160-acre facility is enclosed by a 2.5 m high chain link fence with a 0.6 m wire mesh overhang and a 0.6 m chain link strip along its base. The vegetative community within the facility is 50% native mixed-grass prairie, 10% wetland, and 40% mixed woodland. The site is also used by large ungulates, including moose (*Alces alces*), white-tailed deer, (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus*). There are fluctuating populations of coyote (*Canis latrans*), indigenous waterfowl, passerines, and raptors. The CEI facilities include 3 types of enclosure (single-pair, 1-ha, and 9-ha) to house foxes, an animal health building with kennels for the treatment of ill or injured foxes, separate food preparation and storage facilities. There are also extensive quarantine pens for incoming and outgoing animals.

Breeding age swift foxes were paired and housed in 23 single-pair enclosures. These animals varied in age from juveniles to 14 years. These enclosures averaged 18 m × 12 m in size, were made of 2.5 m × 3 m chain-link panels with a 0.6 m wire mesh overhang along the top and a 0.6 m wide chain-link fencing laid on the ground and filled with rocks. Vegetation in the enclosures was native prairie, but seven also included aspen trees (*Populus tremuloides*). Each enclosure contained 2 artificial den boxes, which consisted of 3 connected chambers covered with an insulated A-frame which is described in more detail in Smeeton and Weagle (2000) and Smeeton *et al* (in prep.).

The 1-ha enclosure was 100 m square in size and constructed as above. The vegetation consisted of aspen groves. The enclosure contained 6 artificial dens, and was used to house a fluctuating number of aged, non-breeding swift fox, mainly females.

The 9-ha enclosure was 400 m × 225 m and constructed identically to the other enclosures. Vegetation was 40% prairie, 10% bog, and 50% mixed aspen and spruce groves. The 9-ha enclosure contained 7 widely spaced artificial den boxes and 1 artificial "mound" (expanded polystyrene on wire over a 3-chambered box). Two artificial dens were in the woodland, with the remaining 6 in the prairie. Six juvenile foxes (3 males and

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3 females) were housed here although only one litter was produced during the 2 years that they remained together in the enclosure.

Breeding Records: The data on breeding biology was obtained from the swift fox studbook maintained by CEI since 1972. Three zoos contributed data to the studbook for varying periods until they discontinued breeding the species. They were the Calgary Zoo (between 1980 and 1993), the Moose Jaw Wild Animal Park (between 1984 and 1994) and Edmonton Valley Zoo (between 1987 and 1995). The swift fox studbook was maintained using SPARKS software (ISIS, 1986).

Animals were paired to guarantee maximum genetic heterozygosity in the captive population, resulting in an inbreeding coefficient of < 0.05 calculated by SPARKS. Prior to that the calculations were done without the aid of SPARKS. We ensured that animals carrying the same bloodlines were not released into the same reintroduction area.

Data Collection: Daily observations of swift fox behavior were recorded during feeding (at dusk, 1700 to 2000 hours depending on season). We recorded the activity of each animal, and noted if an individual was not seen. We used these observations to estimate dates of birth. Without entering the enclosures, we noted any sign of hair removed from the females' abdomen exposing the teats, or the flush of pink in the teats, which indicates the presence of milk. We also noted changes in behavior patterns as an indication that birth had occurred. We assumed the females had whelped if competitive feeding behavior between adults stopped, if females ceased to appear for feeding, and if males began to collect food and carry it into the den. We recorded observations of the female's aggression toward kits when attempting to suckle as an estimate of the age of weaning.

Whelping generally occurred in the artificial den boxes or, in some cases, in underground dens dug by the pair. The male fox provided the female with food for approximately 2 weeks after whelping, when the female rarely left the den. The daily records indicated when females were no longer observed at feeding-times. Once whelping occurred the males tended to spend more time out of the den and were observed collecting and carrying food into the den for the female. When this series of behaviors were observed, the date of whelping was approximately estimated. These dates were checked by back calculations of when the kits were first observed to have emerged from the dens. At CEI, the adults and kits were never handled during the first 6 weeks unless an injury required immediate attention.

Data Analysis: We converted swift fox studbook data to an EXCEL spreadsheet for analysis. These data included the age and number of individuals (males and females) used in the breeding program, the numbers of litters, average litter size, and the birth date of each litter. We conducted student's t-tests to examine differences of litter size among parents' age-categories using the statistical software package SPSS v7.1 (Morris 1993). ANOVA was not used because it would not separate differences between years but only between all the years. The term fecundity is used in this paper to denote the productivity of individual foxes. Due to the importance of limiting disturbance to lactating females, actual litter sizes at birth are unknown. Therefore all calculations regarding litter size are based on kits which actually survived and emerged from the den.

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Results and Discussion

Breeding Population: From 1972 to 1997, CEI used 97 female and 92 male foxes in their breeding program. The initial swift fox came from an animal rehabilitation center in Golden, Colorado; subsequently an additional 28 swift foxes, captured in Colorado, Wyoming, and South Dakota, U.S.A., were added to the breeding population (Table 1). Between 1974 and 1997 329 male and 326 female kits were produced at CEI in 272 litters. The average litter size was 3.6 ± 0.45 kits, and ranged from 1 to 7 kits ($n = 272$). The CEI breeding population has provided 841 swift foxes to the Canadian reintroduction program for release (Smeeton & Weagle, 2000).

Limited observations of swift fox life cycles in wild populations in Canada indicated that both wild and captive foxes have similar behavioral characteristics (Pruss 1993). One striking difference between the captive-born and the wild-born foxes was the life span of the animals. In the wild, death is seldom the result of old age; in contrast, death resulting from old age is the norm within our captive colony. Unpublished data (CEI) on the age of captive-bred released swift fox in the wild indicated that the oldest known captive bred male in the wild was 8 years of age; the oldest known captive bred female in the wild was 6 years of age.

In 1986, the Canadian Swift Fox Recovery Team established a protocol for pairing captive foxes and instituted a minimum period for holding them. The protocol called for an inbreeding coefficient of < 0.05 and that all captive-bred foxes of 4 years old should be released. Swift foxes that were >4 years old at the time of this decision remained with the colony. The goal was a breeding colony of an even age and of wide genetic heterozygosity. Swift foxes paired on a genetic basis will not necessarily breed; other factors (age, compatibility) appear to affect pair breeding success. Following compliance of the policy, the colony consisted of young, newly paired animals, older newly paired animals, and aged animals. Fewer established reproductive pairs remained, resulting in a period of reduced kit production in the captive colony after 1991 (Fig 1.).

We found that when swift foxes were newly paired there were differences in their breeding success, depending on that age of the individuals comprising the pair. In new pairs with yearling females and experienced males, 19% ($n = 37$) of the pairings produced kits in the first year. In pairings with yearling males and experienced females, 18% ($n = 27$) produced kits; and, when both in the pair were yearlings, 11% ($n = 73$) of the pairings produced kits in the first year.

Table 2 summarizes the relationship between age and fecundity for males and females. Yearling females had a lower fecundity [$\alpha = 0.05$] than all other groups except wild-born females. Five-year-old females had a higher fecundity [$\alpha = 0.05$] than all other groups. One-year-old males had a lower fecundity [$\alpha = 0.05$] than most other year classes.

In both the above comparisons, the wild-born males and females in the captive breeding program were separated from the captive-born individuals because their ages could not be determined. The fecundity of the wild-born males and females was generally lower than captive-born foxes, which may be related to their ability to adjust to a captive environment. Once the program began, the wild-born animals were added to the program to maintain genetic diversity. The analysis showed that they were less able to contribute to

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the production of animals for the reintroduction program than the captive-born swift foxes.

Females never produced past the age of 8 years, but males produced until they died of old age (14 years; Table 2). The most productive female had an average litter size of 4.13 kits. The maximum production for a male was 46 kits with an average litter size of 4.18 kits.

Three of 14 females with an average litter size > 4 were siblings but from different litters (Table 2.). A fourth sibling to these females, held at the Moose Jaw Wild Animal Park, also had an average litter size >4 kits per litter ($n = 8$). It was also noted that 6 of 14 females with > 4 kits per litter were from wild-born parents. Because of the lack of information on litter sizes in wild populations it is difficult to make comparisons between captive-bred and wild-born litters.

Figure 2 shows the distribution of birth dates for captive bred litters. Seventy-one percent of the litters produced at CEI were born between 16 April and 10 May. This indicates that the peak of breeding extended from 24 February to 20 March. Litters were born as early as 11 April and as late as 26 June. These observations coincide with the period of bay calling from the first week of February until the first weeks of April (Weagle and Smeeton 1995) within the captive breeding colony. We have observed that breeding may be affected by temperature, with more activity during warmer days, but present data are too limited to confirm this hypothesis.

Established pairs mated earlier in the season than newly paired foxes and bay calling, which was common during the breeding season, no longer occurred after successful mating. Females past breeding age did not call during the breeding season (Weagle and Smeeton 1995).

A critical period in the captive breeding program began in August. By this time, the kits had entered full adolescence and were ready to disperse. Vocal aggression, high-pitched hums, and chittering between the kits were more common. Digging in the single pair enclosures increased markedly. Injuries as a result of active digging along the wired perimeter fencing were more common. In wild populations, food (grasshoppers) was readily available and kits began to disperse from the family unit. Captive-bred kits were best released to the wild during this dispersal period (Weagle and Smeeton 1995) although this may depend on the geographical location of the captive breeding center and the release site.

Summary

1. Both males and females can reproduce in their first year. Females are able to reproduce until their eighth year and males for their entire life.
2. Swift foxes are largely monogamous and it is important that the pair bond should be maintained; pairs should not be separated unnecessarily.
3. The average litter size was 3.6 ± 0.45 kits. Some females consistently produced larger litters.
4. Handling of individuals and disturbance of breeding enclosures between February and June should be kept to a minimum.

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5. Extraction of nursing swift fox kits between birth and 20 days should never be undertaken.
6. Observations have shown that some swift fox individuals will undertake excessive cub carrying behavior if within sight of other pairs. Single pair breeding enclosures should be visually isolated from one other.
7. Housing should be designed to allow efficient capture to reduce handling stress and obviate the use of traps or nooses.
8. Wild animals being brought into the existing colony should be examined, immunized, and quarantined for a minimum of 60 days. Each animal should be quarantined separately. Quarantine facilities should be isolated, and each animal should be provided with an insulated den box and visually barred from seeing any other foxes.

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Table 1. Summary of the sources, numbers and dates imported for the Cochrane Ecological Institute founder Swift fox.

Source	Males	Females	Years
Golden, Colorado (first imports)	2	4	1972
Pierre, South Dakota	1	5	1978 – 1981
Pawnee National Grassland, Colorado	2	1	1980
Weld Co., Colorado	1		1982
Lincoln Co., Colorado	2	2	1982 – 1985
Las Animas, Colorado	1		1987
Laramie Co., Wyoming	1		1990
Laramie Co., Wyoming	2	2	1990 – 1991
Laramie Co., Wyoming	5	3	1994
Total	17	17	

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Table 2. Mean litter size and number (n) of litters in sample by age class¹ and sex of captive-born and wild-born swift fox parents in the captive breeding program, Cochrane Ecological Institute, Alberta, Canada, 1972-1997.

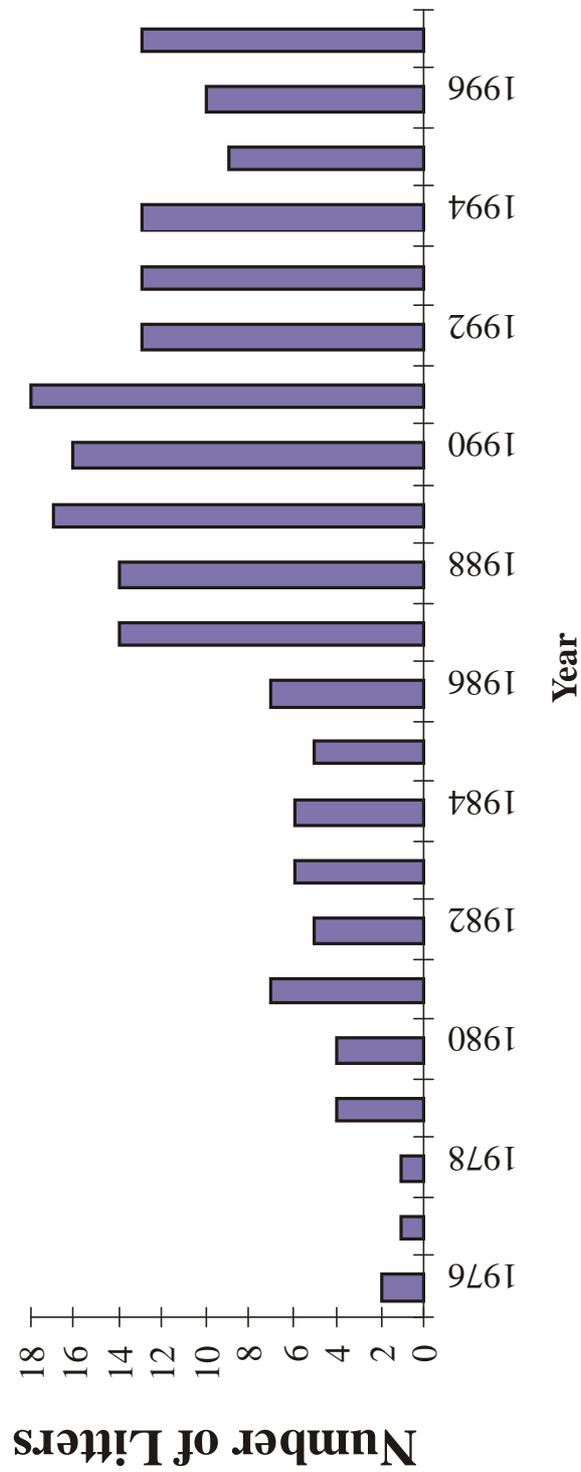
Age	Females ²		Males	
	0	<i>n</i>	0	<i>N</i>
1	3.0	35	3.0	34
2	3.4	41	3.7	38
3	3.5	43	3.9	40
4	4.0	35	3.5	28
5	4.8	23	3.8	17
6	3.8	18	3.8	16
7	3.8	18	3.1	11
8	4.0	9	3.6	9
9	0		4.1	11
10	0		4.1	10
11	0		3.8	4
12	0		4	1
13	0		4	1
14	0		5	1
Wild-born	3.1	50	2.9	51

¹ Age of wild-born adults unknown

² No females bred at age > 8 years

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Figure 1: Numbers of litters per year born at CEI from 1976 to 1997.



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Figure 2: Distribution of birth dates for litters at CEI from 1976 to 1997.

