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Cross-fostering in coyotes: Evaluation of a potential conservation and research tool for canids

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ABSTRACT

Cross-fostering has been attempted opportunistically with endangered canids as a means of increasing populations. Due to the usefulness of cross-fostering for conservation, an understanding of factors influencing success rates is essential. Using captive coyotes (*Canis latrans*) as a model, we assessed the willingness of adult pairs to foster young born to other parents. We assessed the efficacy of fostering pups into existing litters (augmentation) and completely switching litters (replacement). We augmented four litters with two pups of similar age when pups were <7 days old. In addition, we replaced four entire litters when pups were <10 days old. We also augmented litters with pups 3–4 and 6–7 weeks of age. Survival, weight gain, and dominance status of pups were monitored for six weeks and compared to four control litters to determine success. All complete litter replacements were successful with survival rates among replaced pups (89.5%) similar to those of control litters (90%). For augmented litters, pup survival was dependent on the age at which fostering occurred. All pups fostered into 4 litters at <1 week of age survived beyond 6 weeks of age, two of three fostering attempts with 3–4-week-old pups succeeded, while neither of two attempts to foster 6-week-old pups succeeded. Surviving fostered pups appeared to be at no disadvantage. Weight gains were similar for pups in all treatments, and there was no evidence of reduced dominance status among fostered pups as compared to natal pups in the same litters. These results illustrate that genetic relatedness is not essential for successful fostering and does not appear to alter dominance patterns; however the age at which pups are fostered may affect the success of fostering attempts.

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1. Introduction

Cross-fostering, the rearing of non-maternal young by either intraspecific or interspecific surrogate parents, is a potentially useful tool in conservation efforts and research. However, current information on fostering success in canids is limited to anecdotal records and opportunistic attempts. There is little documentation of the inclination of canids to engage in cross-fostering or the factors enhancing or precluding the acceptance of foreign offspring by reproductive females.

Cross-fostering laboratory animals, especially rodents, has been used to study density effects as well as the effects of genetic, behavioral, and nutritional regimes (e.g., Christian and Lemunyan, 1958; McGuire, 1988). For example, Huck and Banks (1980) found interspecific cross-fostering of two species of lemmings (*Dicrostonyx groenlandicus* and *Lemmus trimucronatus*) resulted in altered adult social preferences and behavior.

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Cross-fostering has been used in bird species to evaluate kin recognition and mate choice (Clayton, 1987; Todrank and Heth, 2001; Slagsvold et al., 2002). Fostering has also aided conservation efforts in marsupials (Sterneberg and Rose, 2002), birds (Powell and Cuthbert, 1993; Drewien and Bizeau, 1977), and rodents (Murie et al., 1998).

Cross-fostering of canid pups has several applications for enhancing reproduction in recovery programs of threatened and endangered species. Fostering young can aid conservation efforts by introducing captive-bred young into wild populations to increase the population numerically (US Fish and Wildlife Service, 2004a) or enhance genetic diversity, and provide rearing opportunities for wild young that have been orphaned. Introducing animals into a population as pups allows them to learn natural behaviors, increasing their chances of survival and successful reproduction over animals introduced as adults (US Fish and Wildlife Service, 2004b).

Cross-fostering has been attempted in captive canids during opportunistic events. Fostering attempts have been made in red wolves (*Canis rufus*) with all fostered wolves surviving to weaning (Waddell et al., 2002). In addition, the litter of a female gray wolf (*Canis lupus*) was introduced to another female who had had her pups removed (Goodman, 1990). There have been occasional attempts at cross-fostering canid pups into wild populations. One of two red wolf pups fostered into a wild litter in 1998 survived to weaning (Waddell et al., 2002).

Two captive-born red wolf pups were inserted into a wild litter of two pups in 2002 (US Fish and Wildlife Service, 2004a). Both pups were accepted by the foster mother, remained with the pack, and were seen to exhibit natural behaviors as yearlings. Cross-fostering has also been attempted with Australian dingoes (*Canis familiaris dingo*, pers. comm. L. Corbett) and the endangered African wild dog (*Lycaon pictus*, McNutt personal communication). In 2002, one 6-week-old African wild dog pup was introduced into a litter of five pups. The mother nursed the pup immediately and the pup was still alive two months later.

Thus, there are good indications that cross-fostering can be successful in canids as a population management strategy for threatened and endangered species, and as a tool to facilitate experimental designs. However, information is needed on the success rates and factors influencing success of fostering procedures, especially in threatened species for which controlled studies are logistically difficult. While the coyote (*Canis latrans*) is not threatened, the species makes a good model for other canids. Coyotes share numerous behavioral and physiological attributes with other threatened canids that are relevant to the likelihood of success of fostering, including dominance hierarchies, territoriality, and social suppression of reproduction (e.g., Macdonald and Sillero-Zubiri, 2004). Mating patterns and parental care are often similar among canid species; the pervasive mating system in canids is obligatory monogamy (Kleiman, 1997), canids usually breed once a year, young have a relatively long period of dependency, and bi-parental care is common (Kleiman and Eisenberg, 1973). Since the 1970s, numerous studies have suggested that collaborative care of young may be a fundamental aspect of canid sociology (Macdonald et al., 2004). The use of information gathered on factors influencing fostering success in coyotes for other canids is further warranted by the fact that successful fostering attempts have been made in red wolves and African wild dogs (Waddell et al., 2002; US Fish and Wildlife Service, 2004a; McNutt personal communication). We provide information from a controlled study on the success rates that could be expected from cross-fostering efforts and the effects of fostering on dominance status of litter mates. In addition, we examined the effect of pup age on the probability of acceptance of fostered young.

2. Methods

Coyotes are a monogamous species and it has been shown that mated pairs breed for life (Bekoff and Wells, 1980). Litter sizes generally range between 3 and 12 with both sexes participating in parental care. Pups are weaned between 5 and 7 weeks. Sixteen adult coyote pairs and their litters were maintained in facilities (0.1 ha pens) at the USDA Predator Research Facility, Millville, Utah. Coyotes were fed identical diets obtained from a furbreeders cooperative. All, but 1 parent was captive-bred at the facility, and parents were generally experienced breeders with between 1 and 5 years breeding experience. None of the foster pups were genetically related to foster parents.

We investigated the success of cross-fostering under two regimes: augmenting litters by adding two pups to existing litters (litters then consisted of two fostered pups and two or three natal pups), and complete litter replacement. All litters were standardized to four or five pups in order to avoid bias of litter size in weight and survival measurements. Thus pups from large litters were augmented into small litters, and in one case, two pups from a large litter were removed from the study. We assessed the success of augmentation for pups at three ages: $\leqslant$1 week (4 litters); 3–4 weeks (3 litters); and 6–7 weeks (2 litters). Efforts were made to augment existing litters with pups of similar ages (difference in ages was $\leqslant$3 days for 1-week augments, $\leqslant$9 days for 3–4-week augments, $\leqslant$4 days for 6–7-week augments, and $\leqslant$6 days for replacements). This also reduced the likelihood of introducing a bias from differences in weights of fostered and natal pups; weights of treatment groups were in fact similar (Fig. 1). Where possible, the

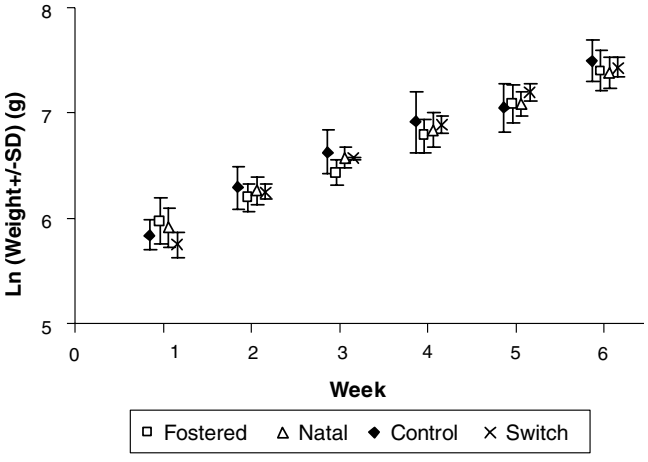

Fig. 1 – Mean weight gains of natal and fostered coyote pups in control, replaced and 1- and 3-week augmented litters.

sex-ratio of augmented litters was equalized. In addition, four litters were completely replaced when pups were <10 days old and four litters were used as control litters. Adult coyotes remained in the pens during all augmentations and replacements to minimize disturbance.

Pups were marked for individual identification by shaving small patches of pelage from various parts of their bodies. Upon introduction of pups to the foster parents, the initial behavioral response of the parents was monitored by observing interactions of parents with foster pups and with natal pups if present. Growth patterns of all pups were assessed by weighing pups twice a week until 3 weeks of age and once per week thereafter. Pups were monitored through 6 weeks of age, allowing enough time for parents to accept or reject pups. The slope of weekly weight gains of pups within litters was log transformed and compared among the treatments using a autoregressive repeated measures analysis of variance. Pup survival rates were compared among the various treatments. Augmentations of 6–7-week-old pups were discontinued after the first two fostering attempts failed.

We obtained preliminary data on the 6-week dominance status of pups within augmented litters to assess the social effects of fostering. All dominance related interactions (e.g., pins, hip slams, and threats) between pups were recorded during $\geqslant$four 45-minute observation sessions until confidence in dominance rankings was achieved. Observations were made from an observation building to minimize disturbance to animals, and were done in the morning to coincide with a high activity period of the pups. Rankings of fostered versus natal pups were assessed using a Fisher's exact test due to low sample sizes. Both sexes were combined in the rankings as early hierarchies (determined by 6 months of age) are unisex (Walls Knight and Stokes, 1978).

3. Results

Survival of pups in control litters and replaced litters was similar (Table 1), with two deaths in one litter of control pups, and two deaths in one litter of replaced pups. Causes of mortality were not confirmed due to the disappearance of the bodies (coyotes often eat young after death). All natal pups in augmented litters survived. Survival of fostered pups in augmented litters appeared dependent on the age at fostering. All eight pups fostered into four litters before the age of one week survived through the end of the study period (when pups were 6-weeks old). Two of three attempts at cross-fostering 3–4-week-old pups were successful with all four fostered pups in two litters surviving the study period. The two fostered pups in the third litter disappeared within two days. The four pups fostered into two litters (two pups each) at 6–7 weeks of age died within 24 h. Observations immediately following introductions of the 6–7-week-old pups showed that one foster mother continuously carried a foster pup in a normal body grasp for 20 min after which the pup appeared dead. Foster parents of the other litter interacted nonviolently with the foster pups for one hour with no indications of rejection, but the pups were missing the next day. Subsequently, additional augmentations of 6–7-week-old pups were discontinued.

We detected no evidence surviving foster pups were at any disadvantage. Weight gains were similar among pups in all treatments (control, replaced, natal, and fostered pups; $F_{18,75} = 0.62$, $P = 0.87$; Fig. 1). In addition, 6-week dominance hierarchies obtained for 4 litters (3 litters augmented at one week of age, and 1 litter augmented at three to four weeks of age) suggested fostering did not put pups at a disadvantage in terms of the dominance status achieved within the litter hierarchy (Fisher's exact $P = 0.24$; Table 2). Instead, dominance status appeared somewhat correlated to the weights of the pups.

4. Discussion

Our results indicate cross-fostering (either augmenting or replacing litters) of week-old coyote pups is highly successful, with survival and weight gain of fostered pups similar to natal and control pups. In addition, since all natal pups in augmented litters survived, fostering procedures do not appear to have a disruptive effect on the parents' ability to rear a litter.

The success of cross-fostering may be influenced by the ability of the parents to recognize, and their motivation to persecute, unfamiliar individuals in the litter. Possible mechanisms allowing animals to discriminate between kin and nonkin are 'recognition by association', whereby animals learn during rearing to recognize familiar individuals, and 'phenotype matching' where animals discriminate kin and nonkin based on genetic relatedness by comparing

Table 1 – Survival rates for coyote litters and pups in control litters, replacement litters, and litters augmented at 1, 3, and 6 weeks of age

Treatment	Sample sizes (*n*)			Percent surviving		
	Litters	Pups		Litters[a]	Pups	
		Natal	Foster		Natal	Foster
Control	4	20	–	100	90	–
Replaced	4	–	19	100	–	89.5
Augmented:						
At 5–7 days	4	9	8	100	100	100
At 3–4 weeks	3	7	6	100	100	66.7
At 6–7 weeks	2	6	4	100	100	0

a Litter survival based upon survival of $\geqslant$1 pup.

Table 2 – Six week dominance status of natal and cross-fostered coyote pups in augmented litters

Litter	Rank in dominance hierarchy			
	1	2	3	4
1	Fostered (338; 6)	Fostered (374; 6)	Natal (218; 3)	Natal (220; 3)
2	Fostered (378; 2)	Natal (466; 5)	Natal (410; 5)	Fostered (332; 2)
3	Fostered (464; 5)	Natal (426; 2)	Fostered (436; 5)	Natal (416; 2)
4	Fostered (948; 30)	Natal (944; 21)	Fostered (1046; 30)	Natal (818; 21)
% Fostered	100	25	50	25
% Natal	0	75	50	75
Mean wt (g)	532.0	552.5	527.5	444.0

Number in parentheses indicates the weight (g) and the age (days) of the pups on the day augmentations were made.

phenotypes (Halpin, 1991). The mechanism of kin recognition appears to be species-specific and dependent on the mating system and social organization (Ferkin and Rutka, 1990). However, many mammals show recognition by association (Bekoff, 1981; Sherman and Holmes, 1985; Ferkin et al., 1992) indicating that kin recognition may develop by familiarity in early life as opposed to a genetic basis as predicted by kin selection theory (Hamilton, 1964). Our results indicate genetic relatedness is not a necessity for acceptance of young by parents in coyotes.

The decreasing acceptance of pups as their age increased suggests the mechanism of recognition of young by parents, or at least the sensitivity of recognition, changes as the young develop. Temporal changes in recognition ability have also been documented in other taxa. Holmes and Sherman (1982) found high success in fostering ground squirrels (*Spermophilus beldingi* and *S. parryii*) when introductions were made within the first 3 days of age, and concluded mother-offspring recognition did not develop until juveniles were active above the ground. In bank swallows, the 'signature calls' that make chicks individually distinctive do not develop until nestlings are 15–17 days of age (Beecher et al., 1981), and thus that chicks' vocal cues could not become part of a kin template until young are at least 2 weeks old. The flank gland odors that golden hamsters can use to recognize their kin are not produced by juveniles until about 30 days of age (Algard et al., 1966). In thick-billed murres (*Uria lomvia*), cross-fostering experiments revealed that parents were less likely to foster a foreign chick as the chick aged (Lefevre et al., 1998). Our results also suggest litter augmentations in canids should occur at an early age to minimize rejection by foster parents.

Cross-fostering could be considered successful as a conservation tool if the fostered individuals survive and reproduce within the population. Fostered animals have reproduced in red wolves; one male fostered into the population in 2002 bred in 2004 and one female fostered in the same year became pregnant (US Fish and Wildlife Service, 2004b). Reproductive success in canids is often correlated with dominance status within the resident pack (e.g., Peterson et al., 2002), and studies in birds have found that fostering can negatively influence an individuals chance of achieving dominant status (Hansen and Slagsvold, 2004). However, our observations indicated that fostering did not put coyote pups at a disadvantage in achieving dominant status within the litter. Thus, fostered coyotes initially accepted by foster parents may increase recruitment into the population. Our results are based on low sample sizes, however, and further research is needed to fully assess the effects of fostering, weight, and age on dominance status in coyote pups.

Successful cross-fostering would also facilitate certain types of research. The ability to readily cross-foster young would increase the potential for a wide range of studies that have previously been difficult to conduct in canids. Such studies may involve issues such as kin recognition, mate choice, and the examination of genetic versus environmental influences on behavior. Cross-fostering also allows for standardized litters (litters of similar size, sex ratios, etc.) to be created which may reduce experimental biases in studies.

Our results demonstrate cross-fostering could be a successful management technique for increasing recruitment to populations of endangered canids, introducing genetic diversity into populations suffering inbreeding depression, or for use as a research tool to generate standardized litters for research purposes. Our results, however, suggest success is highly correlated with the age at which young are introduced into foster litters.

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