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IMMOBILIZATION OF SWIFT FOXES WITH KETAMINE HYDROCHLORIDE–XYLAZINE HYDROCHLORIDE

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ABSTRACT: There is an increasing need to develop field immobilization techniques that allow researchers to handle safely swift foxes (*Vulpes velox*) with minimal risk of stress or injury. We immobilized captive swift foxes to determine the safety and effectiveness of ketamine hydrochloride and xylazine hydrochloride at different dosages. We attempted to determine appropriate dosages to immobilize swift foxes for an adequate field-handling period based on three anesthesia intervals (induction period, immobilization period, and recovery period) and physiologic responses (rectal temperature, respiration rate, and heart rate). Between October 1998–July 1999, we conducted four trials, evaluating three different dosage ratios of ketamine and xylazine (2.27:1.2, 5.68:1.2, and 11.4:1.2 mg/kg ketamine:mg/kg xylazine, respectively), followed by a fourth trial with a higher dosage at the median ratio (11.4 mg/kg ketamine:2.4 mg/kg xylazine). We found little difference in induction and recovery periods among trials 1–3, but immobilization time increased with increasing dosage ($P<0.08$). Both the immobilization period and recovery period increased in trial 4 compared with trials 1–3 ($P\leq0.03$). There was a high variation in responses of individual foxes across trials, making it difficult to identify an appropriate dosage for field handling. Heart rate and respiration rates were depressed but all physiologic measures remained within normal parameters established for domestic canids. We recommend a dosage ratio of 10 mg/kg ketamine to 1 mg/kg xylazine to immobilize swift foxes for field handling.

Key words: Immobilization, ketamine hydrochloride, swift fox, *Vulpes velox*, xylazine hydrochloride.

INTRODUCTION

In 1996, the US Fish and Wildlife Service (USFWS) determined that listing the swift fox (*Vulpes velox*) under the 1973 Endangered Species Act was warranted but precluded by higher priority actions. However, the USFWS requested additional information about the species from state and federal agencies for a continued status review. This finding generated numerous studies to gather information on swift fox ecology and population biology, and prompted the development of the Swift Fox Conservation Team, comprised of state and federal biologists within the historic range of the species. Development of field immobilization techniques that allowed researchers to handle safely swift foxes with minimal risk of stress or injury became a high priority.

At present, no systematic study has been published on the immobilization of swift foxes. Seal and Kreeger (1987) suggested immobilization of swift foxes using ketamine hydrochloride with promazine hydrochloride or xylazine hydrochloride with atropine sulfate, and also mentioned the need for a systematic study. Previous studies have demonstrated the effective use of a combination of ketamine hydrochloride (ketamine) and xylazine hydrochloride (xylazine) for immobilizing canids (Kreeger and Seal, 1986; Kreeger et al., 1990; Travaini et al., 1992).

Ketamine affects the central nervous system, inducing dissociative anesthesia (Wright, 1983). Desirable characteristics of ketamine as an immobilizing agent for wild animals include the retention of normal reflex actions such as coughing and swallowing, suitability for intramuscular injection, non-cumulative effects, and a wide safety margin allowing for general estimation of body weights (Ramsden et al., 1976; Wright, 1983). Muscle rigidity occurs when ketamine is used alone, so it is

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TABLE 1. Least-squares means (LS) and standard errors (SE) for the duration of each time period (min) for each trial dosage of ketamine hydrochloride (KET) and xylazine hydrochloride (XYL), October 1998–July 1999.

Trial	KET (mg/kg)	XYL (mg/kg)	KET : XYL	*n*	Induction period LS ± SE	Immobilization period LS ± SE	Recovery period LS ± SE
1	2.3	1.2	1.9	13	6.3 ± 1.4A[a]	12.9 ± 4.6A	29.1 ± 4.8A
2	5.7	1.2	4.7	14	6.3 ± 1.2A	31.1 ± 4.4B	29.9 ± 4.7A
3	11.4	1.2	9.5	13	3.6 ± 1.2A	40.6 ± 4.6C	32.7 ± 4.8A
4	11.4	2.4	4.7	13	—[b]	64.2 ± 4.6D	47.9 ± 4.8B

[a] Least-squares means within columns followed by a common letter are not significantly different ($P \leq 0.10$; Fisher's LSD).
[b] Data for the induction period for trial 4 were excluded from the ANOVA analysis because the data violated the assumption of equal variances. Mean induction period time for trial 4 was 2.1 min (SE=0.04).

frequently used in combination with xylazine, a sedative analgesic and muscle relaxant (Fuller and Kuehn, 1983). Immobilization with a combination of ketamine and xylazine results in a smooth and rapid induction followed by a smooth but extended recovery (Kreeger and Seal, 1986).

We evaluated different dosages of these combined drugs under controlled conditions to determine an appropriate dosage range to immobilize swift foxes for an adequate field-handling period, while minimizing the recovery time.

MATERIALS AND METHODS

We captured swift foxes in Sherman and Wallace counties in western Kansas (USA) in August of 1996. We transported and held the captured foxes in facilities at Northern Prairie Wildlife Research Center in Jamestown, North Dakota (USA, 46°52′N, 98°38′W). All procedures were reviewed and approved by the Northern Prairie Wildlife Research Center Animal Care and Use Committee. Each fox was paired with an unrelated mate and the pairs were held in separate pens (approximately 3×5×1.5 m), with the exception of two males who were held alone. Two den boxes, one above ground and one below ground, were provided in each pen and foxes could dig dens to 1 m below ground. Foxes were fed daily with frozen commercial canine food (R & R Feeds, Ottertail, Minnesota, USA); water was provided ad libitum. Each fox was immunized for rabies (Defensor®, SmithKline Beecham Animal Health, West Chester, Pennsylvania, USA), canine coronavirus (FirstDose® Pfizer Animal Health, Exton, Pennsylvania, USA), canine distemper, canine parvovirus, infectious canine hepatitis, leptospirosis, and parainfluenza (Vanguard® puppy5/L, Pfizer Animal Health, Exton, Pennsylvania, USA). All foxes were periodically treated for ecto- and endo-parasites (Ivomec®, Merck, Inc., Rahway, New Jersey, USA; Vet-Kem®, Flea & Tick Powder, Sandoz Agro, Inc., Des Plaines, Illinois, USA).

Fourteen adult swift foxes (≥1 yr old; six females, eight males) were used in our study. Four trials were conducted on each fox between October 1998–July 1999, based on four different dosage ratios (Table 1) of a combination of ketamine (Ketaset®, Bristol Laboratories, Division of Bristol-Myers Co., Syracuse, New York, USA) and xylazine (Rompun®, Haver-Lockhart Laboratories, Division of Bayvet Corporation, Shawnee, Kansas, USA). We selected the dosages based on a red fox (*Vulpes vulpes*) immobilization study by Kreeger et al. (1990). We increased the dosage ratio in the first three trials by increasing the ketamine administered and keeping the xylazine constant (Table 1). In trial 4 we used the median dosage ratio (trial 2) but increased the dosage.

Trials were conducted in a laboratory for ambient temperature control and to eliminate inconsistencies in surrounding disturbances. We reduced the biological effects of stress from removing the foxes from holding pens by placing the foxes in dog carriers within a dark, quiet room for a minimum of 20 min prior to the start of the trial.

Immediately prior to administering the immobilization drugs, swift foxes were weighed to determine the amount of drug needed relative to weight. Foxes were easily removed from the dog carriers by covering them with a blanket and then taking hold of the animal by the skin on the back of the neck. Drugs were administered by intramuscular injection into the upper right hindquarter of each animal and the time of injection was recorded. Foxes were then placed on a blanket in a cage (76×61×76 cm). Once the foxes were safe to handle, their eyes

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were lubricated (sterile saline solution) and a cloth was placed over their eyes to minimize the risk of eye injuries from light and limit their response to researchers.

We measured the duration of three periods (induction, immobilization, and recovery) similar to other studies (Hash and Hornocker, 1980; Kreeger et al., 1990). Induction period was defined as the time between initial injection and when the fox was fully immobilized (i.e., head down and unresponsive to touch). Immobilization period was the time between the fox being unresponsive and the moment it first elevated its head. Recovery was the time between the fox spontaneously lifting its head and recovery of all faculties, marked by its ability to walk back into the carrier, although its behavior was not necessarily normal.

Once swift foxes were immobilized, we monitored rectal temperature to the nearest 0.5 C once per minute with a digital thermometer. For a 15 sec interval each minute, heart rate was determined by auscultation (beats/min), and respiratory rate was determined by observing thoracic expansion (breaths/min). These parameters were recorded until termination throughout the immobilization period. Values measured for heart and respiration rates were multiplied by four to determine rate per minute. We determined the average temperature, heart rate, and respiratory rate during the immobilization period for each fox in each trial. Any physical reactions to the drug were noted (e.g., vomiting, excessive salivation, compulsive licking, muscle twitching).

Preliminary analysis did not indicate strong positive or negative correlations among induction, immobilization, and recovery periods, so we analyzed each of these three response variables separately. We used SAS PROC MIXED (SAS Institute, 1989) to perform an analysis of variance (ANOVA) in a randomized block design, with fox as a blocking factor, to compare the durations of the induction, immobility, and recovery periods (Littell et al., 1996). We used the same procedure to compare mean physiologic responses (heart rate, respiration, and body temperature). We used a Type I error rate of $\alpha=0.10$ and verified model assumptions using residual plots. If residual plots for a response variable did not follow a normal distribution, we applied a log transformation and repeated the ANOVA. When we detected differences among trials, we used Fisher's LSD test to conduct multiple comparisons and determine which trials differed (Milliken and Johnson, 1984).

RESULTS

Residual plots for each time period showed no evidence of differences in responses between male and female foxes, hence data from both sexes were pooled together for the analysis. Data for the induction period did not follow a normal distribution and was log transformed. We found no evidence of differences in induction time among trials 1–3 ($F=2.23$, df=2,20, $P\leq0.13$; Table 1). Trial 4 was not included in the analysis for the induction period because the variances in these data were heterogeneous to trials 1–3. Because no difference was detected in the mean induction times for trials 1–3, we calculated the overall mean induction time for the three trials ($\bar{x}=5.2$ min, SE=0.75, $n=36$). The mean induction time for trial 4 was 2.1 min (SE=0.04, $n=13$). Although we could not compare the mean induction time for trials 1–3 with trial 4 statistically, the 2.5 fold decrease in the mean induction time from trials 1–3 to trial 4 indicated a biological difference.

Immobilization period differed among trials ($F=32.2$, df=3,36, $P\leq0.0001$), and multiple comparisons indicated a progressive increase in the amount of time immobilized from trials 1–4 ($P\leq0.08$). We also found strong evidence of differences among trials for the recovery period ($F=3.58$, df=3,36, $P\leq0.02$). Multiple comparisons indicated an increased recovery time between trial 4 and trials 1–3 ($|t|\geq2.29$, df=36, $P\leq0.03$).

Foxes with less than five measurements within trials were excluded from the analysis of mean physiologic responses. Heart rate data were not normal and were log transformed. Mean heart rate was different among trials ($F=4.77$, df=3,29, $P\leq0.008$); multiple comparisons indicated that mean heart rate was the same for trials 1, 2, and 4, but was higher in trial 3 ($|t|\geq1.96$, df=29, $P\leq0.06$; Table 2). Mean respiration rate also differed among trials ($F=7.20$, df=3,29, $P\leq0.0009$). Trial 1 had a higher mean respiration rate than trials 2–4 ($|t|\geq3.06$, df=29, $P\leq0.004$), and trial 3 had a higher rate than trial 4 ($|t|\geq1.73$, df=29, $P\leq0.09$). Finally, we found differences in mean body temperature among

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TABLE 2. Least-squares means (LS) and standard errors (SE) of physiologic responses for each trial, determined from the mean responses of individual foxes, measured each minute during the immobilization period for each trial dosage of ketamine hydrochloride (KET) and xylazine hydrochloride (XYL), October 1998–July 1999.

Trial	KET (mg/kg)	XYL (mg/kg)	KET : XYL	Heart rate (beats/min)		Respiration rate (breaths/min)		Temperature (C)	
				n	LS ± SE	*n*	LS ± SE	*n*	LS ± SE
1	2.3	1.2	1.9	7	90.9 ± 5.5A[a]	7	35.3 ± 2.4A	4	39.5 ± 0.3A
2	5.7	1.2	4.7	13	84.9 ± 4.2A	13	27.9 ± 2.1BC	13	39.4 ± 0.2A
3	11.4	1.2	9.5	13	104.5 ± 4.2B	13	29.6 ± 2.1B	13	38.4 ± 0.2B
4	11.4	2.4	4.7	13	92.0 ± 4.2A	13	27.1 ± 2.1BC	13	38.2 ± 0.2B

[a] Least-squares means within columns followed by a common letter are not significantly different ($P \leq 0.10$; Fisher's LSD).

trials ($F=13.26$, df=3,26, $P \leq 0.0001$), with temperatures higher in trials 1–2 than in trials 3–4 ($|t| \geq 3.13$, df=26, $P \leq 0.004$).

Four foxes in trial 1 experienced adverse effects during immobilization, including excessive salivation, compulsive licking, vomiting, and muscle twitching. In trial 2, four foxes had compulsive licking, vomiting, or both. One fox in trial 4 experienced muscle twitching during induction. No physical reactions were noted during trial 3.

DISCUSSION

Immobilization of swift foxes with a combination of ketamine and xylazine resulted in a smooth induction and smooth but extended recovery. We experienced no deaths or serious adverse effects (e.g., seizures, overheating) sometimes associated with this drug combination (Wright, 1982). We found it difficult to identify an optimal dosage of ketamine and xylazine for swift foxes because of the large variation in responses of individual foxes across trials. However, we were able to establish guidelines for selecting an appropriate dosage with adequate handling time and minimal recovery time.

Six of 13 swift foxes in trial 1 were immobilized <10 min, indicating that the dosage of 2.27 mg/kg ketamine and 1.2 mg/kg xylazine was too low for an adequate field-handling period. Mean induction and recovery periods were similar for the dosage ratios tested in trials 1–3, but the immobilization period increased. Therefore, the ketamine to xylazine ratio of 9.5:1.0 in trial 3 provides the lengthiest handling period while minimizing induction and recovery time (Table 1). In trial 4, the mean immobilization period was >60 min, beyond the time normally necessary for field handling, and the mean recovery period was significantly lengthened.

In general, the physiologic measurements in the four trials did not indicate a health risk and were not a factor in identifying a suitable dosage. However, swift foxes in trials 1 and 2 did experience increased incidences of salivation, compulsive licking, vomiting, and muscle twitching. Food often was available to foxes because of their food caching behavior, thus the vomiting may be attributed to some foxes eating immediately prior to a trial. Womer and Richards (1990) reported a mean heart rate of 141 (beats/min)±6.2 and a mean respiratory rate of 48 (breaths/min)±5.2 for non-restrained swift foxes. Heart rate and respiration rate during the trials were comparatively depressed, but were still within a range of 72–200 beats/min and 11–37 breaths/min established for domestic canids (Altman and Dittmer, 1974). Although mean rectal temperature statistically differed between trials 1–2 and trials 3–4, all trials varied less than a degree from the mean rectal temperature of 39 C±0.2 reported by Womer and Richards (1990).

Overall, we recommend ketamine-xylazine as a safe, effective drug combination

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for immobilizing adult swift foxes in the field. However, we did not include pregnant females in our study, and we found no studies indicating whether the drug combination was safe for immobilizing pregnant swift foxes. Travaini et al. (1992) reported successful births by three pregnant red foxes after being immobilized in late winter, but further study is needed to determine the effects of ketamine-xylazine on birthing success in swift foxes. We suggest using a dosage of approximately 10 mg/kg ketamine and 1 mg/kg xylazine for an average handling time of 40 min. Greater ratios may also be effective but were not tested in our study. Researchers may want to consider using a higher dosage than may seem necessary, because of a potentially high response variance among individual swift foxes. For field procedures, this variance may be compounded by capture stress (Kreeger and Seal, 1986), and the variation in nutritional and health condition of wild swift foxes (Travaini et al., 1992).

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