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SERUM CHEMISTRY VALUES OF THE ENDANGERED SAN JOAQUIN KIT FOX (*VULPES MACROTIS MUTICA*)

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ABSTRACT: Serum chemistry values were obtained from 64 adult San Joaquin kit foxes (*Vulpes macrotis mutica*) in western Kern County, California (USA). The goal of the study was to establish normal chemistry values for this endangered species. No significant differences were found for mean values of alanine aminotransferase (217.1 IU/1), alkaline phosphatase (44.2 IU/1), cholesterol (145.6 mg/dl), total protein (5.8 g/dl), creatinine (0.63 mg/dl), calcium (8.2 mg/dl), albumin (3.0 g/dl), glucose (129.2 mg/dl), amylase (196.8 IU/1), sodium (153.7 mEq/1) and phosphorus (5.42 mg/dl) between sexes or seasons. Significant differences were noted for aspartate aminotransferase, blood urea nitrogen and potassium between seasons. Possible disturbances in normal hepatic and renal functions were noted.

Key words: *Vulpes macrotis mutica*, San Joaquin kit fox, endangered species, serum chemistry.

INTRODUCTION

Measurement of hematologic and serum chemistry values are commonly used as diagnostic techniques for the assessment of health status of individual animals. These parameters may also be useful in assessing health status of populations and may indirectly serve as indicators of habitat condition and changing habitat quality (Franzmann, 1972; Seal et al., 1975; Seal, 1977). In order to correctly evaluate physiological parameters, normal values must be established for that species. This paper presents normal ranges of serum chemistry values for the endangered San Joaquin kit fox (*Vulpes macrotis mutica*), a small canid inhabiting the arid central valley of California. Hematologic values have been previously reported (McCue and O'Farrell, 1987). The distribution, life history and status of this and other subspecies has also been published (O'Farrell, 1987).

MATERIALS AND METHODS

Kit foxes were trapped on the Elk Hills Naval Petroleum Reserve which is located approximately 48 km southwest of Bakersfield, Kern County, California (35°08'N, 119°28'W). An ecological description of Elk Hills was presented by McCue and O'Farrell (1987). Animals were captured in live-traps (National Live Trap Corporation, Tomahawk, Wisconsin 54487, USA) and handled using methods designed to minimize capture stress and excitement. Blood samples (6 to 9 ml) were taken from the jugular vein in 10 ml syringes and transferred immediately into sterile Vacutainers (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey 07070, USA) containing potassium oxalate and sodium fluoride for blood glucose analysis or no anticoagulant for analysis of other biochemical parameters. Blood samples were refrigerated before being shipped by mail to Veterinary Reference Laboratory, Inc. (P.O. Box 25978, Santa Ana, California 92799, USA) on the same day they were collected.

Aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase, blood urea nitrogen (BUN), cholesterol, total protein, creatinine, phosphorus, calcium, albumin, and glucose were analyzed using a SMA-1260 (Technicon, Inc., Tarrytown, New York 10591, USA), amylase was measured by the iodometric method (Van Loon et al., 1951), and potassium and sodium were measured on a Beckman System E-2 (Beckman Instruments, Inc., Fullerton, California 92634, USA).

The mean and standard deviation (SD) were calculated for each data set. Aberrant values that differed from the mean by greater than three standard deviations were classified as "outliers" and excluded (Lumsden and Mullen, 1978; Lumsden et al., 1979). Statistics for data sets were recalculated subsequently with the "outliers" removed. Ranges of normal chemistry values were calculated based on two standard deviations above and below the mean. This statistical method also was used for calculating normal hematological ranges of kit fox (McCue and O'Farrell, 1987). Means of chemical variables were examined for differences between sexes and seasons (summer, August–September;

TABLE 1. Blood chemistry values of adult San Joaquin kit foxes sampled in western Kern County, California, between 1981–82 that did not differ between sexes or seasons.

Value	Units	Sample size (n)	Mean ($\bar{x}$)	SD	Normal range ($\bar{x} \pm 2$ SD)
ALT	(IU/l)	63	217.1	112.9	0–443
Alkaline phosphatase	(IU/l)	62	44.2	32.6	0–109
Cholesterol	(mg/dl)	64	145.6	43.1	59–232
Total protein	(g/dl)	64	5.8	0.6	4.6–7.0
Creatinine	(mg/dl)	63	0.63	0.29	0.1–1.2
Calcium	(mg/dl)	62	8.2	0.96	6.3–10.1
Albumin	(g/dl)	64	3.0	0.36	2.3–3.7
Glucose	(mg/dl)	61	129.2	28.8	72–187
Amylase	(IU/l)	58	196.8	68.7	59–335
Sodium	(mEq/l)	58	153.7	2.5	149–159
Phosphorus	(mg/dl)	62	5.42	1.7	2.0–8.9

winter, November–January) using analysis of variance techniques (SAS Institute Inc., 1985). Differences were considered to be significant when $P < 0.05$.

RESULTS

Blood samples were collected from 64 (34 males, 30 females) adult (>6-mo-old) kit foxes. Mean values of ALT, alkaline phosphorus, cholesterol, total protein, creatinine, calcium, albumin, glucose, amylase, sodium and phosphorus were not significantly different between sexes or seasons (Table 1). AST levels were significantly higher in winter than summer, while BUN and potassium levels were significantly higher in summer than winter (Table 2).

DISCUSSION

Alanine aminotransferase (ALT) is an enzyme found within hepatocytes and is elevated in serum following hepatocyte plasma membrane damage or hepatocellular degeneration (Meyer, 1982). Plasma half-life for ALT is approximately 2.5 hr (Zinkl et al., 1971) and persistence of elevated serum enzyme levels may reflect continued enzyme leakage (Meyer, 1982). Ninety-five percent of the kit foxes had ALT levels greater than the normal range for domestic dogs (Wolford et al., 1986), coyotes (*Canis latrans*) (Rich and Gates, 1979), red foxes or silver foxes (*V. vulpes*) (Benn et al., 1986). Factors that may be associated with the elevated liver enzyme levels in San Joaquin kit foxes include infectious canine hepatitus virus, which is known to be present in the fox population (McCue and O'Farrell, 1988), parasites, toxins and heavy metals.

Aspartate aminotransferase (AST) is an enzyme that is not liver specific because it

TABLE 2. Blood chemistry values of adult San Joaquin kit foxes sampled in western Kern County, California, between 1981–82 that differed between sexes or seasons.

Value	Units	Variables*	Sample size (n)	Mean ($\bar{x}$)	SD	Normal range ($\bar{x} \pm 2$ SD)
AST	(IU/l)	S	30	158.7	79.0	1–317
		W	29	306.4	164.0	0–634
BUN	(mg/dl)	S	31	37.2	12.1	13–61
		W	28	24.7	4.1	17–33
Potassium	(mEq/l)	S	26	5.03	0.3	4.43–5.63
		W	29	4.75	0.3	4.15–5.35

* S, summer; W, winter.

is present in both the liver and skeletal muscle. Elevations in AST in kit foxes sampled in winter, with no significant elevation in ALT, suggest extrahepatic tissue damage releasing AST. The mean serum AST level was also higher than means reported for domestic dogs (Wolford et al., 1986), coyotes (Rich and Gates, 1979), red foxes or silver foxes (Benn et al., 1986).

A majority of blood urea is synthesized in the liver from ammonia, which is formed from protein catabolism or absorbed from the gastrointestinal tract (Duncan and Prasse, 1983). The kidney is the most important route of urea excretion and BUN concentration is often used as an indicator of renal function. BUN also may increase due to decreased kidney perfusion, high protein diet, increased protein catabolism, and post-urinary obstruction or leakage. Elevated BUN levels in kit foxes, especially in summer, may have been due to a combination of factors including high protein diet, severe environmental stress, nephrotoxins and infectious disease, such as leptospirosis. However, no antibodies against five serotypes of *Leptospira interrogans* were found during a serologic survey of the Elk Hills kit foxes (McCue and O'Farrell, 1988). Captive swift foxes provided with adequate water (Mainka, 1988) had a mean BUN similar to kit foxes sampled in the winter when kit foxes were presumably experiencing less water stress. It was inferred that the increase in BUN in the summer was related to water balance, although differences in protein content of diet may also be involved. A decrease in urine volume accompanying efforts to conserve body water may have caused the elevation in BUN. However, creatinine levels which are also used to monitor renal function, were not significantly different between summer and winter.

Serum phosphorus concentration in adult kit foxes was elevated compared with values reported for adult dogs (Wolford et al., 1986) and coyotes (Smith and Rongstad, 1980). Seal et al. (1975) postulated that high serum levels of phosphorus in wolf (*Canis lupus*) pups may have been due to high phosphorus intake from a meat diet which had a 1:20 calcium to phosphorus ratio. This probably does not explain the high phosphorus levels in kit foxes because they consume the entire carcass of their prey and probably have a more balanced calcium and phosphorus intake. Hyperphosphatemia has been associated with prerenal azotemia (Ross, 1986) and may, therefore, be related to aspects of water balance in kit foxes. Serum phosphorus elevations may also be due to methods of sample handling, because phosphorus is released from red blood cells after 12 to 24 hr, and from hemolysis (Duncan and Prasse, 1983).

Glucose elevations in captured wild animals are primarily attributed to stress (Karns and Crichton, 1978; Seal et al., 1975; Smith and Rongstad, 1980). Glucocorticoid release antagonizes the effects of insulin, leading to an elevation in blood glucose by decreasing glucose uptake and use by tissues. Methods were developed to minimize stress on captured foxes, but some individuals become hyperexcited during initial stages of handling. No attempt was made to quantify levels of stress observed: instead, every effort was made to minimize or prevent it.

Serum levels of alkaline phosphatase, cholesterol, total protein, creatine, calcium, and albumin in adult kit foxes did not differ significantly between sex or season, nor were they different from ranges reported for adult domestic dogs (Wolford et al., 1986), coyotes (Smith and Rongstad, 1980), red foxes or silver foxes (Benn et al., 1986). Levels of sodium in kit fox were at the upper range of normal or slightly higher than normal values for the domestic dog (Duncan and Prasse, 1983). Amylase levels in kit foxes were lower than those reported for dogs (Duncan and Prasse, 1983).

Interpretation of serum chemistry values must be made in relation to the physiology and ecology of the species sampled.

The kit fox is a carnivore inhabiting an extremely arid environment, where little or no free water is available. Foxes occasionally were observed drinking what free water was available, but aspects of water balance in this species are not well understood. The causes for the elevation of liver enzymes and BUN, and the electrolyte imbalances observed during this study are presently unknown. It is possible that some values in kit foxes may represent adaptations to extremes in environmental conditions and the unpredictability of food and water resources.

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