Journal of Zoo and Wildlife Medicine 21(4): 414–424, 1990

EFFECTS OF CAPTURE AND TRANSLOCATION ON BIOLOGICAL PARAMETERS IN FREE-RANGING BLACK RHINOCEROSES (*DICEROS BICORNIS*) IN ZIMBABWE

Michael D. Kock, B.Vet.Med., M.P.V.M., Raoul du Toit, M.S., Nancy Kock, M.S., D.V.M., Dougal Morton, B.Pharm., Ph.D., Chris Foggin, B.V.Sc., Ph.D., and Beverley Paul, M.B.B.S., M.R.C.Path.

Abstract: Sixty-four free-living black rhinoceroses (*Diceros bicornis*) were chemically immobilized in the Zambezi Valley and Midlands of Zimbabwe in 1988. Animals were transported under sedation 1–200 km to holding bomas and maintained 1–80 days before being translocated. Physiological parameters (temperature, respiration, pulse) were measured at capture, during transport from the capture site to holding bomas, and before anesthetic reversal. Serial blood samples were collected at capture (sampling period 1, $n = 50$), after transport from capture site to holding bomas (sampling period 2, $n = 52$), and following various periods of boma confinement (sampling period 3, $n = 32$). Hematologic parameters, including red blood cell count (RBC), hemoglobin (Hb), packed cell volume (PCV), white blood cell count (WBC), and differential WBC counts were determined for the three sampling periods. Red blood cell indices were measured for sampling periods 1 and 3 only. Biochemical parameters were determined for sampling periods 1 and 3 and included cortisol, creatine phosphokinase (CPK), lactic dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase, total protein, albumin, globulin, albumin:globulin ratio, blood urea nitrogen (BUN), creatinine, glucose, magnesium, phosphorus, calcium, sodium, potassium, chloride, total bilirubin, and cholesterol. Selected biochemical parameters were determined during sampling period 2 and included cortisol, CPK, LDH, AST, ALT, BUN, creatinine, glucose, sodium, potassium, and chloride. Individual rhinoceroses were placed into normal or stressed outcome classifications at capture. Measurements of selected biological parameters revealed differences ($P < 0.05$) in cortisol and glucose values related to capture stress. Comparisons of biological parameters over sampling periods 1–3 revealed differences ($P < 0.05$) in cortisol, CPK, LDH, AST, glucose, total bilirubin, calcium, magnesium, phosphorus, potassium, chloride, creatinine, BUN, albumin, globulin, cholesterol, Hb, PCV, and WBC counts and differentials. These differences reflected the physiologic response of the black rhinoceros to acute and chronic stressors. Although no animals died at capture, there was an indirect mortality rate of 14% (9/64) at 1 wk–2 mo postcapture.

Key words: Black rhinoceros, *Diceros bicornis,* capture, transport, translocation, physiology, hematology, stress.

INTRODUCTION

Because of the precipitous decline in the numbers of black rhinoceroses (*Diceros bicornis*) in Africa,[17] Kenya, Namibia, and Zimbabwe have adopted aggressive management programs. Black rhinoceroses in Zimbabwe are under severe poaching pressure, particularly in the lower Zambezi Valley (16°00′S, 29°30′E). Zimbabwe's aggressive campaign includes anti-poaching patrols and chemical capture and translocation of rhinoceroses to secure areas.

The limited availability of physiological data on the black rhinoceros has been recently reviewed.[17] Baseline biological data have recently been established from black rhinoceroses captured in Zimbabwe.[17] A few reports in the literature have attempted to evaluate the effects of acute (capture, transport) and chronic (confinement) stressors on

From the Department of National Parks and Wildlife Management, P.O. Box 8365, Causeway, Harare, Zimbabwe (M. Kock); Clinical and Paraclinical Veterinary Studies, Faculty of Veterinary Science, University of Zimbabwe, Harare, Zimbabwe, and International Wildlife Veterinary Services, 1850 North Main Street, Salinas, California 93906, USA (M. and N. Kock); World Wide Fund for Nature, Zambezi Rhino Project, P.O. Box 8437, Causeway, Harare, Zimbabwe (du Toit); the Departments of Pharmacy (Morton) and Hematology (Paul), School of Medicine, University of Zimbabwe, Harare, Zimbabwe; and Veterinary Research Laboratory, P.O. Box 8101, Causeway, Harare, Zimbabwe (Foggin).

biological parameters in domestic animals[23] and wild animals,[9] but no reports have dealt specifically with free-ranging black rhinoceroses.

This paper provides further biological data collected from the black rhinoceros after chemical immobilization[17,20] and subsequent to capture and examines the response of this species to acute and chronic stress. Details are also provided on the long-term survival of translocated animals.

MATERIALS AND METHODS

Methods of capture, anesthesia, biological data collection, and blood processing and analyses have been previously reported.[17,20] Comparisons were made between hematologic parameters measured at the different sampling periods, including red blood cell count (RBC), hemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell count (WBC), and differential WBC counts. Biochemical parameters that were determined for stress comparisons among sampling periods included cortisol, creatine phosphokinase (CPK), lactic dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (ALP), total protein (TP), albumin, globulin, albumin:globulin (A/G) ratio, blood urea nitrogen (BUN), creatinine, glucose, magnesium, phosphorus, calcium, sodium, potassium, chloride, total bilirubin, and cholesterol. Each animal was classified into an outcome category at capture based on evaluation of the animal before darting, during induction, and on clinical examination during anesthesia. An animal experiencing rapid induction (within 6–13 min after darting) without complications was placed in the normal outcome category. A rhinoceros was categorized as stressed if it experienced a prolonged chase before darting, some agitation and excitement during darting, and an extended induction period (>13 min after darting) with significant struggling, sweating, and signs of exhaustion including open-mouthed breathing or if immobilization generally was poor.

Blood samples collected at capture (sampling period 1) were used to determine baseline values.[17] After capture, individual rhinoceroses were rolled onto a flat wooden sled, and cushions were placed under the head and lower fore- and hind legs to prevent bruising. No padding was placed under the chest or abdomen. The animal was roped to the sled (Fig. 1) and sustained in lateral recumbency for the journey to the holding bomas, which usually involved travel over bush roads. Blood samples for sampling period 2 were collected in the recovery boma immediately before reversing anesthesia with a drug antagonist.[20] Blood samples for sampling period 3 were collected following loading of the lightly narcotized animals[20] into crates for translocation after various periods of boma confinement (1–80 days).

Methods of data entry into a microcomputer and analyses using a statistical graphics program have been described.[17] The data were organized according to sampling period and stress classification and were coded for analyses. Differences in values among the three sampling periods and between the normal and stressed groups were evaluated statistically using a one-way analysis of variance (ANOVA, StatGraphics, Statistical Graphics Corp., Rockville, Maryland 20850, USA). Significant results ($P < 0.05$) were evaluated further using Tukey's HSD for factor-level means.[4] Prior to statistical analysis, each data set was evaluated for distribution patterns, and those parameters that were distributed log-normally were transformed logarithmically before further analysis.

RESULTS

The time from immobilization to blood sampling is summarized in Table 1. The mean time for sampling period 3 (15 days) was not a true representation because six animals were confined for periods ranging from 40 to 80 days. The values for these

Figure 1. Chemically immobilized black rhinoceros in lateral recumbency on transport sled before loading onto the flatbed of a truck. Note restraint ropes and padding under head.

animals skewed the data, and, therefore, the median value (3.5 days) provides a more representative time frame.

Evaluation of biological parameters collected at capture comparing normal with stressed animals (Table 2) revealed significant differences ($P < 0.001$) in cortisol and glucose values. These differences remained significant for glucose values following transport but not for cortisol. Other parameters were not significantly different ($P > 0.05$) between categories.

There were no differences ($P > 0.05$) in physiological parameters (body temperature, respiration, pulse rate) at capture, during transport, and just before reversing anesthesia among the three sampling periods (Table 3). However, there were several highly significant differences among biochemical parameters measured over sampling periods 1–3 (Table 4). Mean cortisol concentration increased ($P < 0.001$) from baseline values after transport but returned to baseline after boma confinement. Fifteen rhinoceroses sampled after boma confinement showed a decline in cortisol concentrations below baseline. In two animals, cortisol levels declined to 0.72 and 0.92 μg/dl.

Table 1. Mean, median, standard error of the mean (SEM), and range of time from immobilization[a] to blood sampling periods 1, 2, and 3 from black rhinoceroses captured and translocated in Zimbabwe.

Blood sampling period	*n*	Mean	Median	SEM	Range
1—sample at capture (min)	50	28	18	4.1	1–158
2—sample following transport[b] (min)	52	178	162	10.1	53–351
3—sample after boma confinement (days)	32	15	3.5	4.1	1–80

[a] Immobilization refers to time at which animal became recumbent or immobile following darting with narcotic(s).
[b] Transport from capture site to holding bomas; time taken from immobilization.

Table 2. Comparison of selected biological parameters[a] of black rhinoceroses placed in normal or stressed outcome categories at capture.[b]

Parameter	Normal		Stressed	
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE
Cortisol (μg/dl)	27	1.69 ± 0.08[c]	19	2.41 ± 0.15[d]
Creatine phosphokinase (IU/L)	29	285 ± 22	23	329 ± 38
Lactic dehydrogenase (IU/L)	24	1,107 ± 58	18	1,179 ± 92
Aspartate transaminase (IU/L)	28	79 ± 4.4	24	88 ± 4.1
Glucose (mg/dl)	28	70.2 ± 6[c] (3.9)[e]	24	128 ± 10[d] (7.11)[e]
Blood urea nitrogen (mg/dl)	28	9.8 ± 0.4 (3.5)[e]	22	10.1 ± 0.5 (3.6)[e]
Creatinine (mg/dl)	28	1.16 ± 0.04 (103)[f]	23	1.23 ± 0.06 (109)[f]
Sodium (mEq/L)	17	133 ± 1.8	17	134 ± 1.4
Potassium (mEq/L)	23	4.47 ± 0.09	19	4.3 ± 0.12
Chloride (mEq/L)	24	93.4 ± 0.96	19	93.21 ± 0.95
White blood cells (WBC) (×10⁹/L)	28	10.5 ± 0.66	22	9.82 ± 0.45
Absolute differential WBC counts				
Segmented neutrophils	28	4.62 ± 0.3	22	5.1 ± 0.4
Band neutrophils	11	0.16 ± 0.03	11	0.14 ± 0.02
Eosinophils	28	0.73 ± 0.09[c]	21	0.46 ± 0.07[d]
Lymphocytes	28	4.4 ± 0.47	22	3.6 ± 0.31
Monocytes	25	0.52 ± 0.07	21	0.45 ± 0.06

[a] Results determined from blood samples collected at capture (mean time from capture = 28 min).
[b] Means within rows with different superscripts ([c, d]) are different ($P < 0.05$).
[c] Units = mmol/L.
[f] Units = μmol/L.

Cortisol levels over the three sampling periods for these two animals were 3.36, 4.99, and 0.92 μg/dl, and 1.82, 1.96, and 0.72 μg/dl, respectively. Cortisol levels were also evaluated according to the time of day that blood samples were collected, as has been reported for other wildlife species.[15,32] Blood samples collected between 0600 and 1000 hr had a mean cortisol concentration of 1.85 μg/dl ($n = 20$), whereas those collected between 1000 and 1400 hr were higher (2.35 μg/dl, $n = 13$, $P < 0.05$). Between 1400 and 1800 hr, cortisol concentrations averaged 1.83 μg/dl ($n = 13$), which was less than the mean value measured during midday. These results were biased by the number of rhinoceroses placed in the stressed category at capture. Of those rhinoceroses captured between 0600 and 1000 hr, only 25% (five of 20 animals) were considered stressed. Seventy percent (nine of 13) of the animals captured between 1000 and 1400 hr were considered stressed, and 38% (five of 13) captured between 1400 and 1800 hr were considered stressed.

Mean CPK and AST levels increased over time ($P < 0.001$) among sampling periods 1–3. Mean LDH levels did not change ($P > 0.05$) between sampling periods 1 and 2 but increased at period 3 ($P < 0.001$). Mean ALP levels were different ($P < 0.008$) between sampling periods 1 and 3, but this finding may have been affected by the sampling at capture of several young animals that were not subsequently sampled after confinement.[17] Mean glucose levels increased between periods 1 and 2 and then decreased between periods 2 and 3 ($P < 0.001$). Although mean TP values measured at capture and after boma confinement did not differ ($P > 0.05$), mean albumin decreased ($P < 0.05$), globulin increased ($P < 0.05$), and the A/G ratio decreased ($P < 0.05$) after boma confinement. Mean total

Table 3. Physiologic data from black rhinoceroses: comparison of temperature, respiration, and pulse at capture, during transport, and before anesthesia reversal.

Parameter	At capture		During transport		Before anesthesia reversal	
	n	$\bar{x} \pm$ SE	*n*	$\bar{x} \pm$ SE	*n*	$\bar{x} \pm$ SE
Temperature (°C)	50	38.7 ± 0.13	13	38.7 ± 0.11	34	38.4 ± 0.12
Respiratioins/min	51	11 ± 0.83	7	9 ± 1.3	32	12 ± 0.73
Pulse (beats/min)	43	79 ± 3.8	5	60 ± 3.5	29	77 ± 2.8

bilirubin values increased ($P < 0.001$) between sampling periods 1 and 3, whereas mean calcium, magnesium, and phosphorus all decreased ($P < 0.03$). Mean BUN was not different ($P > 0.05$) between sampling periods 1 and 2 but increased by period 3 ($P < 0.002$). Mean creatinine and cholesterol values decreased ($P < 0.02$) over time. Mean potassium values between sampling periods 1 and 2 were not different ($P < 0.05$); however, these values decreased ($P < 0.002$) by period 3. In contrast, mean sodium values did not differ ($P > 0.05$) during the study, but chloride values increased ($P < 0.001$) between sampling periods 1 and 3.

Over the three sampling periods, there were no differences ($P > 0.05$) in mean RBC counts, MCV, MCH, MCHC, lymphocytes, or eosinophils (Table 5). However, mean Hb increased after transport but decreased after confinement ($P < 0.002$), as did mean PCV values ($P < 0.001$). Mean WBC counts were lower ($P < 0.05$) immediately after capture compared with after transport or confinement. Neutrophil and band neutrophil counts increased over time ($P < 0.003$), and the absolute monocyte count after transport and confinement decreased ($P < 0.002$) compared with immediately after capture.

Data were also analyzed on the basis of boma confinement for 1 wk versus >1 wk (up to 80 days), and parameters differing significantly are presented in Table 6. Mean CPK and LDH levels ($P < 0.05$) decreased with the extended boma period; LDH values eventually returned to normal (baseline), whereas the CPK values remained high. Glucose values decreased ($P < 0.006$) with longer confinement and eventually returned to baseline levels. In contrast, magnesium levels increased ($P < 0.01$) in those animals maintained for extended periods. Creatinine levels decreased ($P < 0.04$) to below the normal range after an extended boma period, and potassium levels increased ($P < 0.001$) over the confinement period. The WBC and neutrophil counts decreased ($P < 0.05$), whereas the eosinophil count increased ($P < 0.005$) with the extended boma confinement.

The mortality rate for black rhinoceroses translocated in 1988 was 14% (nine of 64). Two of these deaths were considered accidents and the remaining seven deaths followed signs of translocation-related morbidity. One hundred fifty-one adult and subadult black rhinoceroses (excluding hand-raised unweaned calves) were translocated to private ranches from 1986 to early 1989. Of these, approximately 18 (12%) deaths were probably related to combinations of physiological and behavioral translocation stress. In each case, death occurred within 2 mo of translocation. Of the 18 rhinoceroses that died in this manner, 11 (61%) were adult and subadult females, and of the eight adult females, half were pregnant. This suggested a reduced ability of animals in this group to cope with translocation stress.

DISCUSSION

There are a few reports available on the effects of various stressors on the physiological response to capture.[3,6,9,11,16,18,27,28] Re-

Table 4. Biochemical data collected from black rhinoceroses: comparisons of values for blood samples collected at capture, following transport, and after boma confinement.[a]

Parameter	At capture		After transport		After confinement	
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE
Cortisol (μg/dl)	46	1.98 ± 0.1[b]	50	3.29 ± 0.14[c]	26	2.05 ± 0.2[b]
Creatine phosphokinase (IU/L)	52	296 ± 21[b]	48	392 ± 34[c]	27	2,138 ± 283[d]
Lactic dehydrogenase (IU/L)	41	1,075 ± 48[b]	49	970 ± 41[b]	27	1,521 ± 155[c]
Aspartate transaminase (IU/L)	51	81.4 ± 3.2[b]	49	98 ± 3.9[c]	22	162 ± 17[d]
Alanine transaminase (IU/L)	50	24.1 ± 1.2	49	24.8 ± 1.4	27	20.5 ± 2.5
Alkaline phosphatase (IU/L)	44	217 ± 38[b]	—	—	18	54 ± 6.4[c]
Glucose (mg/dl)	50	93.4 ± 6.9[b] (5.14)[e]	49	176 ± 5.9[c] (9.7)[e]	27	152 ± 11.2[d] (8.35)[e]
Total protein (g/L)	54	82.3 ± 0.9	—	—	28	84.6 ± 1.6
Albumin (g/L)	42	37 ± 0.6[b]	—	—	29	29.2 ± 0.7[c]
Globulin (g/L)	42	45 ± 0.7[b]	—	—	28	55.6 ± 1.5[c]
Albumin:globulin ratio	42	0.82[b]	—	—	28	0.53[c]
Total bilirubin (mg/dl)	51	0.41 ± 0.02[b] (7.05)[f]	—	—	13	0.69 ± 0.06[c] (7.05)[f]
Calcium (mg/dl)	54	11.5 ± 0.15[b] (2.86)[e]	—	—	28	10 ± 0.18[c] (2.51)[e]
Magnesium (mg/dl)	54	2.6 ± 0.07[b] (1.06)[e]	—	—	21	1.8 ± 0.16[c] (0.81)[e]
Phosphorus (mg/dl)	54	3.69 ± 0.14[b] (1.18)[e]	—	—	32	3 ± 0.21[c] (1.02)[e]
Blood urea nitrogen (mg/dl)	49	10 ± 0.3[b] (3.57)[e]	49	10.1 ± 0.35[b] (3.6)[e]	27	11.7 ± 0.74[c] (4.31)[e]
Creatinine (mg/dl)	53	1.18 ± 0.03[b] (105)[f]	46	1.02 ± 0.05[c] (90)[f]	27	1.06 ± 0.59[c] (94)[f]
Cholesterol (mg/dl)	49	87.5 ± 2.9[b] (2.26)[e]	—	—	21	75.5 ± 13[c] (1.95)[e]
Sodium (mEq/L)	35	135 ± 1.4	26	134 ± 3.1	27	135 ± 0.71
Potassium (mEq/L)	43	4.43 ± 0.07[b]	29	4.36 ± 0.18[a]	27	3.75 ± 0.11[c]
Chloride (mEq/L)	45	93 ± 0.7[bc]	26	94 ± 0.97[bd]	27	99.8 ± 0.88[d]

[a] Means (±SE) with different superscripts ([b, c, d]) are different ($P < 0.05$)
[e] Units = mmol/L.
[f] Units = μmol/L.

cent studies have attempted to evaluate the responses to stress by examining and quantifying selected biological parameters.[9,16] Assessment of the metabolic condition of wild animals in their natural habitat has been reported,[27] but little attention has been given to the effects of capture, confinement, and translocation on morbidity, mortality, and selected biological parameters.

Stress was originally defined as a nonspecific reaction with three phases: alarm, resistance (fight/flight), and exhaustion.[29] Recent research[8,9,24] has indicated that marked species differences exist and that the stress response consists of behavioral, autonomic, and neuro-endocrine components that rarely occur in isolation.[9] Other workers suggest that stress should be measured by examining the overall response of the animal, its well being, and any effects on reproduction, immunity, and metabolism.[5,7,24] Measuring the change in concentrations of defined "stress" variables using an objective measure of response based on a percent maximal change of the variables has been suggested as an accurate assessment of the physiological response to stress.[9] Studies of North American bighorn sheep (*Ovis canadensis*) classified individuals as normal or stressed at capture and evaluated the ac-

Table 5. Hematologic data from black rhinoceroses: comparison of values from blood samples collected at capture, following transport, and after boma confinement.[a]

Parameter	At capture		After transport		After boma confinement	
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE
Red blood cells (×10¹²/L)	49	5.31 ± 0.08	38	5.43 ± 0.1	31	5.09 ± 0.15
Hemoglobin (g/dl)	49	16.2 ± 0.26[b]	42	17 ± 0.27[c]	30	15.4 ± 0.4[d]
Packed cell volume (%)	51	42 ± 0.67[b]	44	44 ± 0.67[c]	28	39 ± 0.87[d]
Mean corpuscular volume	46	79.3 ± 0.96	—	—	27	78.1 ± 2.1
Mean corpuscular hemoglobin	47	30.8 ± 0.33	—	—	29	30.5 ± 0.73
Mean corpuscular hemoglobin concentration	48	39.1 ± 0.65	—	—	28	39.3 ± 0.83
White blood cells (WBC) (×10⁹/L)	52	10.14 ± 0.4[b]	46	11.7 ± 0.7[cd]	30	11.55 ± 0.52[d]
Absolute differential WBC counts						
Segmented neutrophils	51	4.8 ± 0.2[b]	42	6.8 ± 0.5[c]	30	7.7 ± 0.4[d]
Band neutrophils	23	0.14 ± 0.02[b]	40	0.29 ± 0.04[c]	26	0.46 ± 0.08[d]
Eosinophils	50	0.6 ± 0.06	34	0.46 ± 0.06	8	0.34 ± 0.08
Lymphocytes	51	4.1 ± 0.3	43	3.6 ± 0.3	30	3.0 ± 0.2
Monocytes	48	0.5 ± 0.045[b]	36	0.35 ± 0.4[cd]	26	0.31 ± 0.03[d]

[a] Means with different superscripts ([b, c, d]) are different ($P < 0.05$).

curacy of these classifications based on selected biological parameters. Attempts were also made to verify findings against follow-up field observations.[16] Recent studies suggest that stress can be measured objectively but cannot be based upon a single parameter.[9] In our study of the black rhinoceros, both blood cortisol and glucose concentrations were higher in "stressed" compared with "normal" animals.

Cortisol has been used in domestic species to assess stress related to penning, confinement, changes in environment, and slaughter.[1,22,23] Several wildlife investigators have evaluated the role of cortisol in the stress response,[2,5,14,16,31,33] but the use of cortisol as an indicator of stress levels remains controversial. Circulating cortisol concentration alone is a poor predictor of stress in bighorn sheep[16] and pronghorn antelope (*Antilocapra americana*).[27] Free-ranging white rhinoceroses (*Ceratotherium simum*) show a significant cortisol response when stressed.[33] In our study, serum cortisol levels increased significantly after transport from baseline (capture) levels and then returned to baseline after confinement, indicating recovery from the initial capture exercise. Low cortisol concentrations detected in some animals may indicate adrenal exhaustion from stressors related to capture and confinement. However, one adult female with a cortisol level of 1.63 μg/dl at capture, which increased to 3.52 μg/dl after transport, was loaded into a crate for translocation after a 4-day boma confinement. During this event, she was aggressive and struggled until exhausted; cortisol concentration at the latter time was 4.54 μg/dl.

Physiologic parameters were not affected by capture or transport. The wide range in body temperatures at capture (36.5–41.2°C) probably reflected the variation among animals in exertion associated with capture. The response to stress and hyperthermia was profuse sweating. Respiratory rates declined after immobilization, and in some animals, respiratory depression occurred, although none required emergency treatment. This decline in respiration reflected the deep narcosis induced by etorphine[13,20], the respiratory rates slowly increased with elimination of the narcotic.

Elevations in CPK are indicative of active or recent muscle damage, and persistent elevations are consistent with ongoing damage.[12] In humans, CPK levels may increase 10-fold after muscle injury or vigorous ex-

Table 6. Biochemical and hematologic data from black rhinoceroses: comparison of values between animals maintained in a boma for ≤1 wk versus >1 wk.[a]

Parameter	1–7 days		8–80 days	
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE
Creatine phosphokinase (IU/L)	21	2,407 ± 324[b]	6	1,200 ± 424[c]
Lactic dehydrogenase (IU/L)	21	1,660 ± 185[b]	6	1,032 ± 149[c]
Glucose (mg/dl)	21	165 ± 11[b] (9.21)[d]	6	96 ± 19[c] (5.3)[d]
Magnesium (mg/dl)	14	1.33 ± 0.12[b] (0.55)[d]	9	2.5 ± 0.23[c] (1.03)[d]
Creatinine (mg/dl)	21	1.13 ± 0.06[b] (100)[e]	6	0.83 ± 0.14[c] (73.3)[e]
Potassium (mEq/L)	21	3.51 ± 0.08[b]	6	4.58 ± 0.15[c]
White blood cells (WBC) ($\times 10^9$/L)	23	12.1 ± 0.6[b]	7	9.6 ± 0.88[c]
Absolute differential WBC counts				
Neutrophils	23	8.36 ± 0.4[b]	7	5.7 ± 0.6[c]
Eosinophils	3	0.11 ± 0.02[b]	5	0.52 ± 0.07[c]

[a] Means with different superscripts ([b, c]) are different ($P < 0.05$).
[d] Units = mmol/L.
[e] Units = μmol/L.

ercise and then return to normal in approximately 5 days.[25] In rhinoceroses, CPK values increased between capture and release in the bomas but also increased sixfold after the boma confinement period. These high levels likely reflected the aggressive nature of some animals. The AST profiles mimicked those for CPK, although the overall increase was smaller. In the horse, elevated AST levels accompanied by decreasing CPK values indicate that muscle damage is no longer active.[12] Although CPK levels decreased in the black rhinoceroses, these levels were still considerably elevated above baseline after various periods of boma confinement.

Mean LDH values of 270 IU/L and 526 IU/L have been reported in captive[26] and free-ranging[33] white rhinoceroses, respectively. Values of 474 IU/L have been reported for other captive populations of black rhinoceroses.[21] Baseline values in our study were high by comparison.

The baseline glucose concentration of 92.5 mg/dl (5.14 mmol/L) from rhinoceroses sampled at capture were comparable to values for the white rhinoceros (83 mg/dl; 4.6 mmol/L)[26] and horse (95 mg/dl; 5.27 mmol/L).[12] The increases in glucose levels after transport and sedation may have resulted from acute stress, the influence of glucocorticoids and epinephrine (increased gluconeogenesis), and effects of xylazine,[2] as well as chronic stress with boma confinement. Serum proteins are sensitive to nutritional influences, but in most cases, the changes are subtle and difficult to interpret.[12] In this study, no significant differences were measured in TP, although albumin decreased and globulin increased. This may be explained by the effects of chronic stress, both traumatic and nutritional, which may have increased nitrogen loss, adrenal activity, and protein turnover.[12] Serum protein changes in black rhinoceroses were also reflected by the declining A/G ratio, which was considerably higher than that reported for the white rhinoceros.[10]

Potassium and chloride values were comparable to those for the white rhinoceros.[26,33] However, potassium values decreased with time to below baseline after boma confinement (median = 3.5 days), which may have been related to nutritional intake.[12] However, potassium values in-

creased in those animals maintained in confinement for extended periods (up to 80 days), which was probably related to a high dietary intake of potassium[12] associated with lucerne and cube supplementation.

Hematologic data can be of value in evaluating stress response and health status of wild animals.[9,16,27] Data collected from black rhinoceroses revealed several significant findings related to capture, transport, and confinement. Increased Hb and PCV levels at capture and after transport may reflect stress.[3,25,28] White blood cell counts and differential cell counts reflected a stress leukogram, including a leukocytosis, neutrophilia, lymphopenia, and eosinopenia at capture and after transport. This trend continued during boma confinement, and although the WBC count did not increase between sampling periods 2 and 3, the neutrophilia increased and was accompanied by a left shift, probably resulting from stress and inflammation. Baseline WBC counts for captive black rhinoceroses[21] are significantly lower than those measured in this study. Animals in longer confinement demonstrated more normal WBC profiles, which probably reflected adaptation and resolution of tissue damage and inflammation. The eosinophil counts were of particular interest. The marked eosinophilia present at capture probably was a consequence of parasitism. The eosinophil count in our study animals was significantly greater than that measured in captive black rhinoceroses.[21]

Mortalities in translocated black rhinoceroses often are not detected before autolysis or scavengers damage the carcasses because of the difficulties in postcapture monitoring and the geographic remoteness of the private ranches, national parks, and safari areas to which animals are translocated. Several postmortem examinations have been performed,[19] and observations on these results and data collected during the boma confinement period have revealed significant problems related to capture and confinement. Trauma-induced horn loss appears to be a major risk factor contributing to mortality. An alarming number of animals developed major medical problems associated with horn loss, including secondary infection and septicemia[19] or myiasis, particularly the Old World screwworm (*Chrysomya bezziana*). Of the 151 adult and weaned subadult rhinoceroses translocated to private ranches from 1988 to early 1989, 16% (24) lost their front horns or experienced severe nasal injuries while attempting to smash the walls of bomas and crates, and of the injured animals, 29% (seven of 24) subsequently died.

Prior to 1988, translocated black rhinoceroses were not monitored adequately, except on some private ranches. The precise survival status in rhinoceroses translocated to areas of Wildlife Estate lands is largely unknown, but a substantial number of these animals probably died soon after release. The overall mortality rate (14%) for these translocated animals is unacceptable, particularly because the species is endangered. The black rhinoceros appears to be less susceptible to many of the common capture complications encountered during or shortly after chemical immobilization; however, confinement and translocation appear to play a more significant role in the ultimate survival of some animals. Peracute and acute capture stress/myopathy[30] appear to be unimportant. However, the physiologic responses to capture and the initial period of management indicate significant shifts in parameters that might predispose the animals to the adverse effects of further stress (trauma, nutritional imbalances, infections),[7] as is supported by the high mortality rate that occurs 1 wk–2 mo after capture. Mortalities have been documented over 12 mo after translocation[19] and may be, in some cases, indirectly related to capture, confinement, and translocation. Nutritional stress (translocation occurs in the winter when browse is in short supply) and intraspecific aggression are probably major predisposing factors contributing to mortality.

A National Conservation Strategy for the

black rhinoceros[34] in Zimbabwe recently has been formulated, and an additional 100 rhinoceroses will be captured and translocated in 1991 and 1992. Major goals of future programs are to improve monitoring after translocation and to reduce mortalities. Management recommendations based on findings from this study and on-going research into the effects of capture and translocation, with additional data collected from mortalities, will be developed and implemented to enhance the chances of long-term survival of the black rhinoceros in Zimbabwe.

Acknowledgments: We thank the Director, Department of National Parks and Wildlife Management, Harare, Zimbabwe, for permission to collect blood samples and Professor G. Hill and Dr. J. Ogaa, Faculty of Veterinary Science, University of Zimbabwe, for support. Special thanks go to Mike la Grange, Jenny Hoffmann, Eddie Tiran, Peter, Jane, and Justin Seymour-Smith (Iwaba Wildlife Estate), Eleanor and Alan Lowe (Mazuri Ranch), Drs. Rick Clark and Dave Jessup, and the numerous other individuals visiting or living in Zimbabwe who assisted both in the field and laboratory. Financial assistance was provided by International Wildlife Veterinary Services, Inc., the World Wide Fund for Nature, the Zimbabwe National Conservation Trust, the National Geographic Society, Rhino Rescue USA, and Rio Tinto Zimbabwe, Ltd.

LITERATURE CITED

1. Benson, G. J., P. H. Langer, J. C. Thurmon, D. R. Nelson, C. Neff-Davis, L. E. Davis, W. J. Tranquilli, and B. K. Gustafsson. 1986. Plasma cortisol and norepinephrine concentrations in castrated male pigs maintained in pairs in outdoor pens and in a confinement finishing house: assessment of stress. Am. J. Vet. Res. 47: 1071–1074.

2. Bubenik, G. A. 1982. Chemical immobilization of captive white-tailed deer and the use of automatic blood samplers. *In:* Nielsen, L., J. C. Haigh, and M. E. Fowler (eds.). Chemical Immobilization of North American Wildlife. Wisconsin Humane Society, Milwaukee, Wisconsin. Pp. 335–354.

3. Cheney, C. S., and J. Hattingh. 1988. Effects of chemical immobilization on the blood composition of the impala (*Aepyceros melampus* Lichtenstein). J. S. Afr. Vet. Assoc. 3: 13–18.

4. Daniel, W. W. 1983. Biostatistics: A Foundation for Analysis in the Health Sciences, 3rd ed. John Wiley & Sons, New York, New York. Pp. 206–264.

5. Franzmann, A. W., A. Flynn, and P. D. Arneson. 1975. Serum corticoid levels relative to handling stress in Alaskan moose. Can. J. Zool. 53: 1424–1426.

6. Franzmann, A. W., and E. T. Thorne. 1970. Physiologic values in wild bighorn sheep (*Ovis canadensis canadensis*) at capture, after handling and after captivity. J. Am. Vet. Med. Assoc. 157: 647–650.

7. Griffin, J. 1989. Stress and immunity: a unifying concept. Vet. Immunol. Immunopathol. 20: 263–312.

8. Hattingh, J. 1986. Physiological measurement of stress. S. Afr. J. Sci. 82: 612–614.

9. Hattingh, J. 1988. Comparative quantitation of the physiological response to acute stress in impala and roan antelope. Comp. Biochem. Physiol. 89A: 547–551.

10. Hattingh, J., L. Bomzon, E. Marcus, C. Jooste, M. F. Ganhao, C. S. Cheney, and V. de Vos. 1983. Concentration and composition of plasma proteins in wild animals. Comp. Biochem. Physiol. 75A: 441–445.

11. Hattingh, J., P. G. Wright, V. de Vos, I. S. McNairn, M. F. Ganhao, M. Silove, G. Wolverson, and S. T. Cornelius. 1984. Blood composition in culled elephants and buffaloes. J. S. Afr. Vet. Assoc. 55: 157–164.

12. Kaneko, J. J. 1980. Clinical Biochemistry of Domestic Animals, 3rd ed. Academic Press, London, U.K.

13. Keep, M. E., J. L. Tinley, K. Rochat, and J. V. Clark. 1969. The immobilization and translocation of black rhinoceros *Diceros bicornis* using etorphine hydrochloride (M99). Lammergeyer 10: 4–11.

14. Kirkpatrick, J. F., C. B. Baker, J. W. Turner, Jr., R. M. Kenney, and V. K. Ganjam. 1979. Plasma corticosteroids as an index of stress in captive feral horses. J. Wildl. Manage. 43: 801–804.

15. Kirkpatrick, J. F., L. Wiesner, C. B. Baker, and M. Angle. 1977. Diurnal variations of plasma corticosteroids in the wild horse stallion. Comp. Biochem. Physiol. 57A: 179–181.

16. Kock, M. D., R. K. Clark, C. E. Franti, D. A. Jessup, and J. Wehausen. 1987. Effects of capture on biological parameters in free-ranging bighorn sheep: evaluation of normal, stressed and mortality outcomes, and documentation of long term survival. J. Wildl. Dis. 23: 652–662.

17. Kock, M. D., R. du Toit, D. Morton, N. Kock, and B. Paul. 1990. Baseline biological data collected from chemically immobilized, free-ranging black rhinoceroses (*Diceros bicornis*) in Zimbabwe. J. Zoo. Wildl. Med. 21: 283–291.

18. Kock, M. D., D. A. Jessup, R. K. Clark, and C. E. Franti. 1987. Effects of capture on biological parameters in free-ranging bighorn sheep: evaluation of drop-net, drive-net, chemical immobilization and the net-gun. J. Wildl. Dis. 23: 641–651.

19. Kock, N., M. Kock, A. Pawandwa, and T. Matambo. 1989. Postmortem findings in translocated rhinoceros (*Diceros bicornis*) in Zimbabwe. Sonderdruck aus Verhandlungsbericht des 31. Int. Symp. über die Erkrankungen der Zoo- und Wildtiere, Dortmund. Pp. 275–279.

20. Kock, M. D., M. la Grange, and R. du Toit. 1990. Chemical immobilization of free-ranging black rhinoceros (*Diceros bicornis*) using combinations of etorphine (M99), fentanyl, and xylazine. J. Zoo Wildl. Med. 21: 155–165.

21. Maruska, E. J., B. L. Dresser, and B. D. Barden (eds.). 1986. Black Rhinoceros International Management Survey. American Association of Zoological Parks and Aquariums Species Survival Plan. Cincinnati Zoo and Wildlife Research Foundation, Cincinnati, Ohio. 95pp.

22. McNatty, K. P., and A. Young. 1973. Diurnal changes of plasma cortisol levels in sheep adapting to a new environment. J. Endocrinol. 56: 329–330.

23. Mitchell, G., J. Hattingh, and M. Ganhao. 1988. Stress in cattle assessed after handling, after transport and after slaughter. Vet. Rec. 123: 201–205.

24. Moberg, G. P. 1984. Biological response to stress: key to assessment of animal well-being? *In:* Moberg, G. P. (ed.). Animal Stress. American Physiological Society, Bethesda, Maryland. Pp. 27–50.

25. Rose, L. I., J. E. Bousser, and K. H. Cooper. 1970. Serum enzymes after marathon running. J. Appl. Physiol. 29(3): 355–357.

26. Seal, U. S., R. Barton, L. Mather, and C. W. Gray. 1976. Baseline laboratory data for the white rhinoceros (*Ceratotherium simum simum*). J. Zoo Anim. Med. 7: 11–16.

27. Seal, U. S., and R. L. Hoskinson. 1978. Metabolic indicators of habitat condition and capture stress in pronghorns. J. Wildl. Manage. 42: 755–763.

28. Seal, U. S., J. J. Ozoga, A. W. Erickson, and L. J. Verme. 1972. Effects of immobilization on blood analyses of white-tailed deer. J. Wildl. Manage. 36: 1034–1040.

29. Selye, H. 1973. The evolution of the stress concept. Am. Sci. 61: 692–699.

30. Spraker, T. R. 1982. An overview of the pathophysiology of capture myopathy and related conditions that occur at the time of capture of wild animals. *In:* Nielsen, L., J. C. Haigh, and M. E. Fowler (eds.). Chemical Immobilization of North American Wildlife. Wisconsin Humane Society, Milwaukee, Wisconsin. Pp. 83–118.

31. Spraker, T. R., C. P. Hibler, and G. D. Niswender. 1985. The use of serum concentrations of cortisol as a means of measuring chronic stress in bighorn sheep. Proc. Am. Assoc. Zoo Vet. P. 120.

32. Turner, J. C. 1984. Diurnal periodicity of plasma cortisol and corticosterone in desert bighorn sheep demonstrated by radio-immunoassay. Can. J. Zool. 62: 2659–2665.

33. Van Heerden, J., R. H. Keffen, J. Dauth, and M. J. Dreyer. 1985. Blood chemical parameters in free-living white rhinoceros *Ceratotherium simum*. J. S. Afr. Vet. Assoc. 56: 187–189.

34. Zimbabwe Department of National Parks and Wildlife Management. In press. National Conservation Strategy for Black Rhinoceros. Zimbabwe DNPWM, P.O. Box 8365, Causeway, Harare, Zimbabwe.

Received for publication 2 October 1989.